Testing aftershock decaying model by using aftershocks from the relocated earthquake catalog in Taiwan

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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 16 aftershock sequences, and 3 secondary aftershock sequences around the Taiwan area to test the decaying model. The magitude of these events ranges from M_L 5 to M_L 6.5 Our result suggests that relaxation time t_r may be proportional to $1 / S(0^-)$. Also, the initial seismcity rate (n_{t+}) in a secondary aftershocks sequence is proportional to the seismicity rate right before the secondary mainshock (n_t)

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)

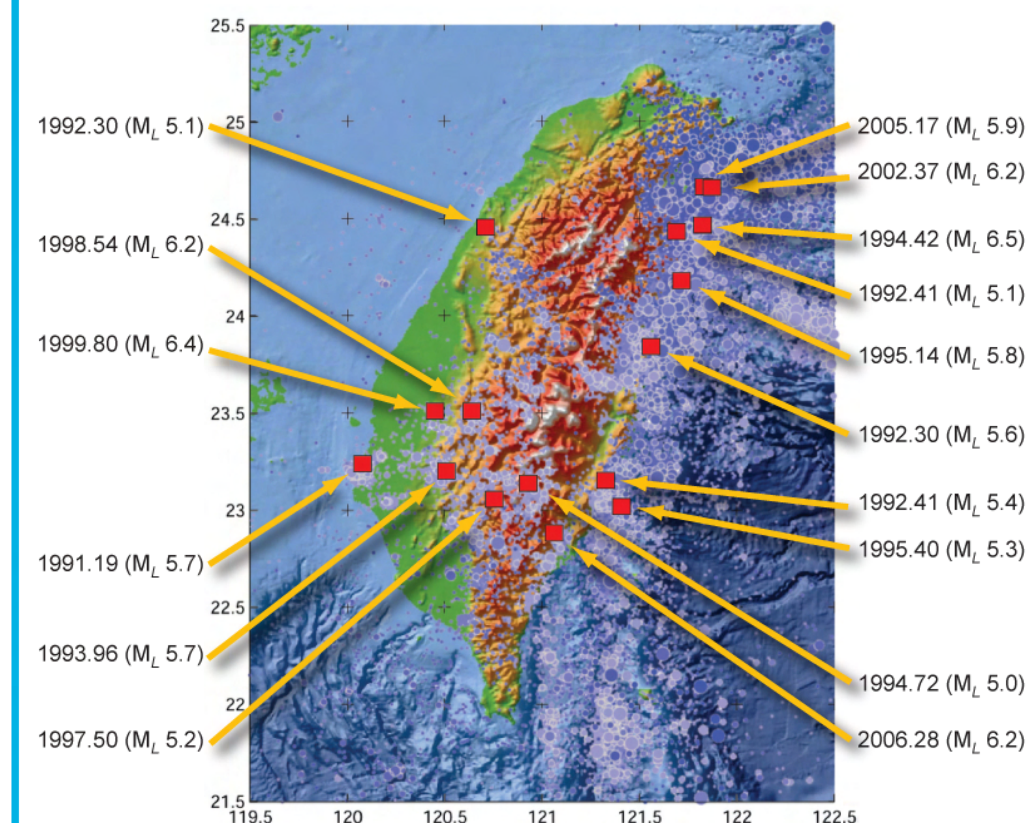
$$n(t) = \frac{n(0^-)}{\left[(\frac{1}{d^{\frac{1}{p}}} - 1)\exp(\frac{-t}{t_r}) + 1 \right]^p}$$

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



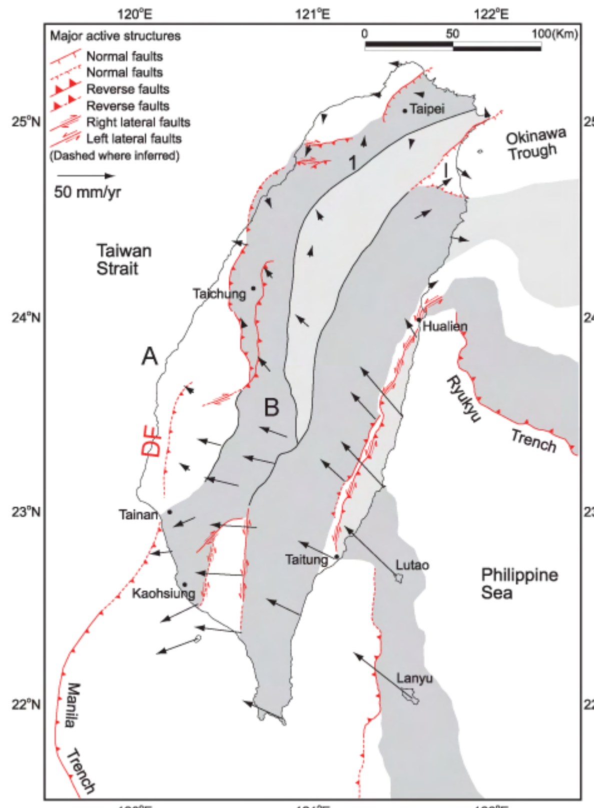
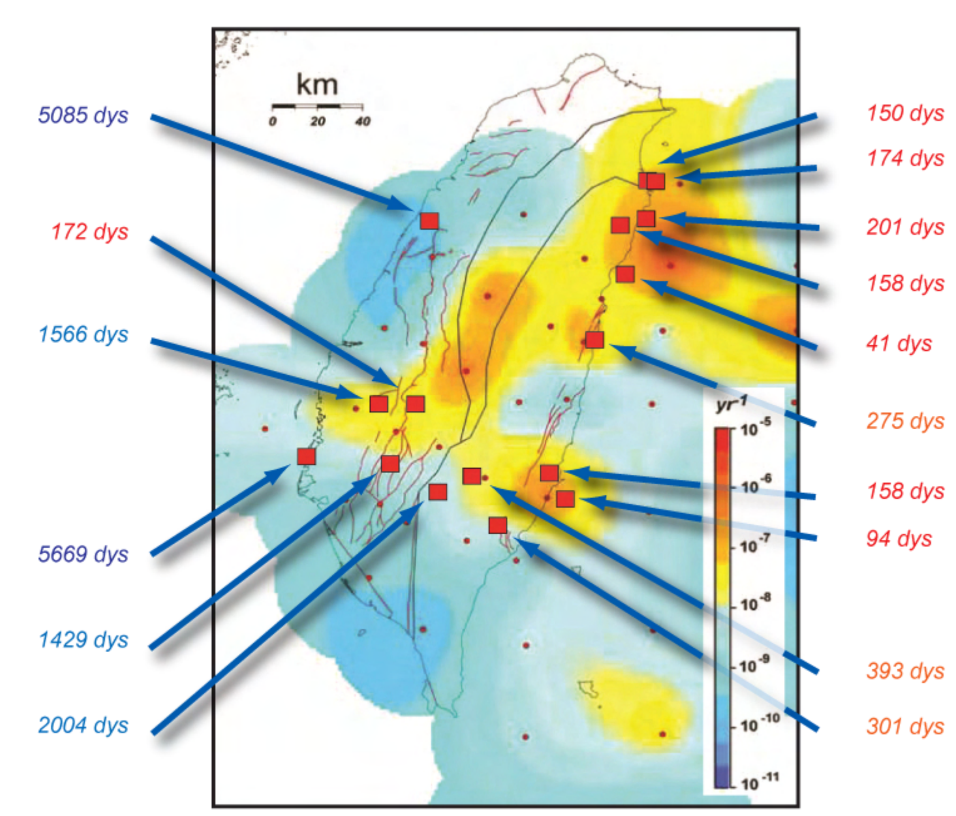


Fig. 1 Regional seismicity (1991-2007) and 16 selected shallow events (< 30 km) in Taiwan area. Each of them are followed by a series of aftershocks in the surrounding area (6-10 km in radius). The local magnitude of mainshocks are from CWBSN catalog.

Fig. 2 Active tectonic setting and major tectonic elements of Taiwan (Shyu *et al.*, 2005). The major active fault are shown in red. The different color shows different tectonic elements in this island. Black arrows show GPS vectors before the *Chi-Chi* earthquake relative to the stable Eurasian continental shelf (Yu et al.,1997). This map show the events we select are located in different tectonic domains, and with different stress field.



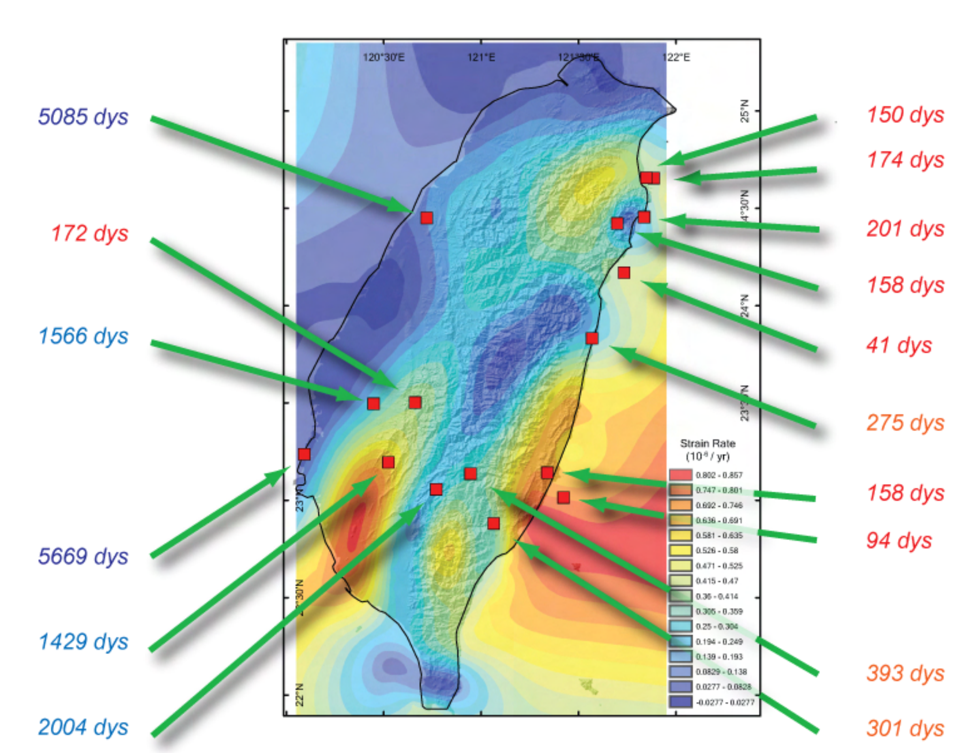
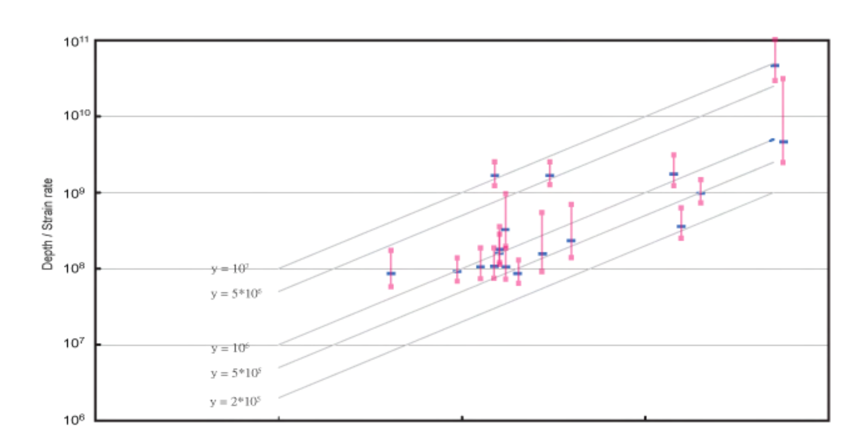


Fig. 3 Relaxation time (Tr) of 16 selected events in different strain rate area. Two strain rate maps come from different estimation method.
(UP) Crustal max. shear strain rates in 0–30 km depth (1995-2005) modified from *Mouthereau et al.(2009), Fig. 6C.* Their estimation is based on the seismic activities
(Down) Max. dilatation strain rate from interseismic GPS observations. This map is modified from *Hsu et al.(2009), Fig. 4C*. It is based on the GPS observation before Chi Chi earthquake in 1999.



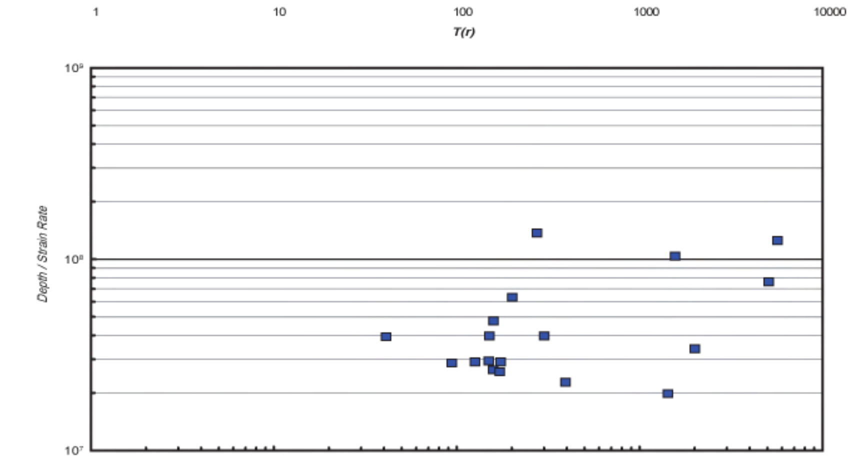


Fig. 4 Relationship between relaxation time (tr) and depth / strain rate for these select events. **(UP)** Crustal max. shear strain rates from *Mouthereau et al.(2009)* **(Down)** Max. dilatation strain rate from *Hsu et al.(2009), Fig. 4C.* These two dataset do not show consistence relationship to select events

Secondary aftershocks in main decay sequence

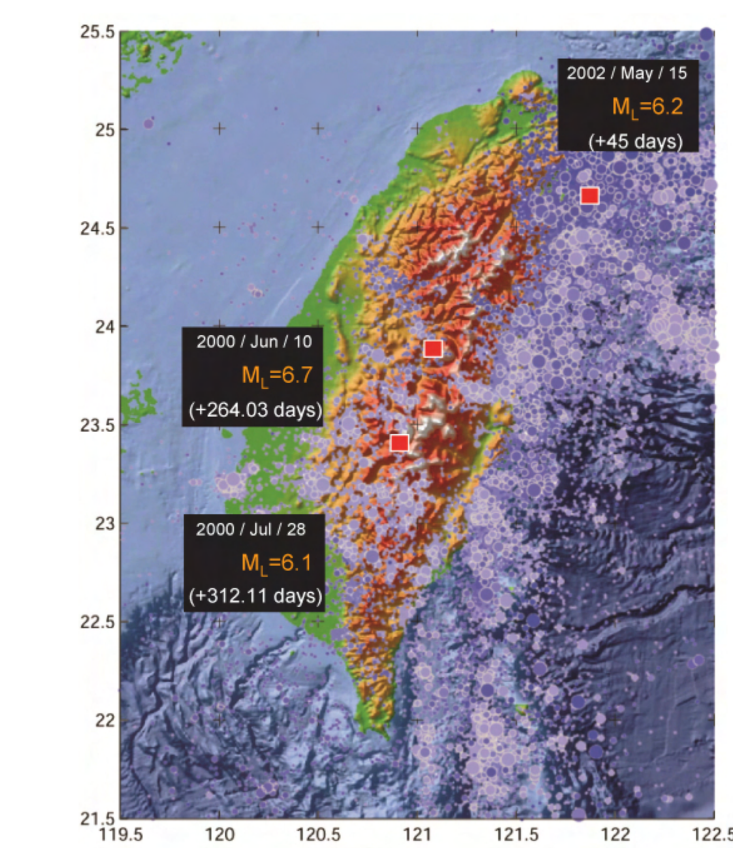


Fig. 5 Three selected secondary mainshocks in this study. 2 of these events occured after *Chi Chi earthquake (Mw 7.6) in 1999. One occured after Ilan earthquake (Mw 6.8) in 2002. The remote aftershocks from Ilan earthquake are also used in previous analysis.*

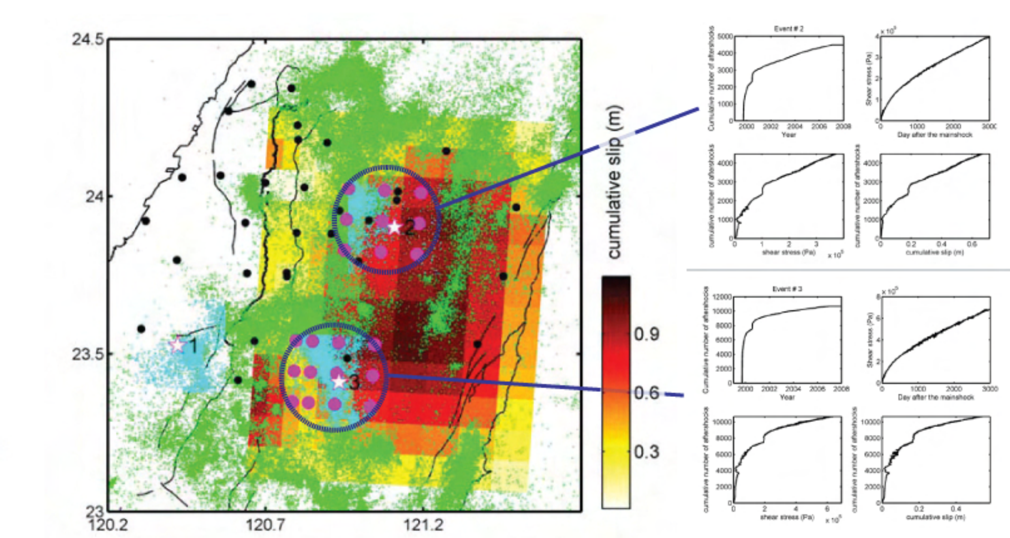


Fig. 6 Post-seismic deformation after the Chi-Chi earthquake in the Central Taiwan (Y. Hsu 2009). Stars show the location of select secondary mainshock. Their afterslip, shear stress history and cumulative number of aftershocks are ploted in the right side. Both of them show imperfect relationship in aftershocks and shear stress history.

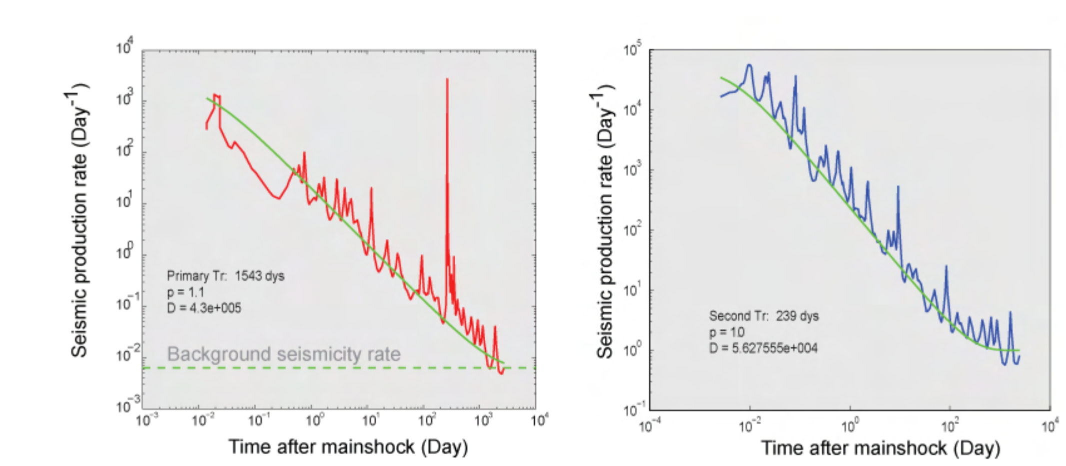


Fig. 7 Modeling result of the M=6.7 earthquake sequence. Left part shows the fitting result for the seismicity rate that is directly affected by the *Chi-Chi* earthquake (Mw=7.6). Green line shows the fitting cruve. For the secondary aftershocks (the high peak in the middle) we use the ratio between 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.

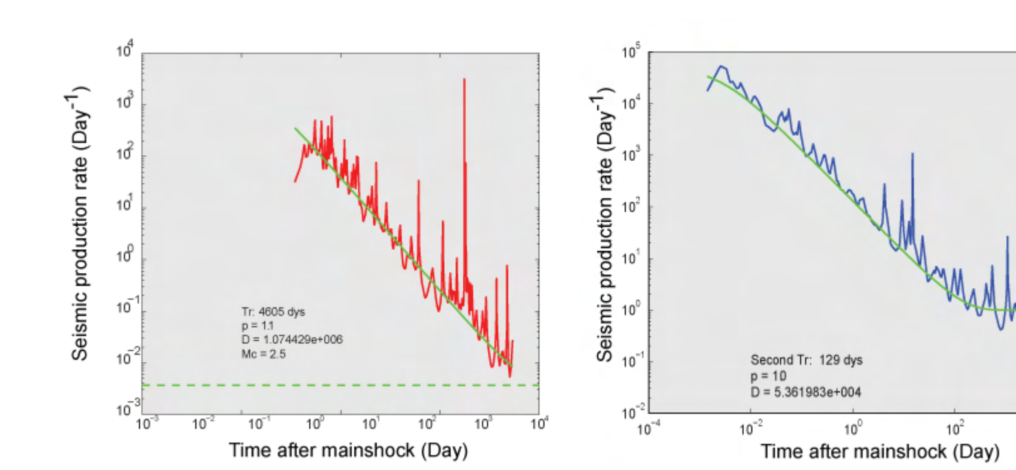


Fig. 8 Modeling result of the M=6.1 earthquake sequence. Left part shows the fitting result for the seismicity rate that is directly affected by the *Chi-Chi* earthquake (Mw=7.6). Green line shows the fitting cruve. The relaxation time of its secondary aftershock are about 2 times longer than the M=6.7 event. It can be resulted from the minor misfit of the primary aftershock decay, or controled by the local change of aftership.

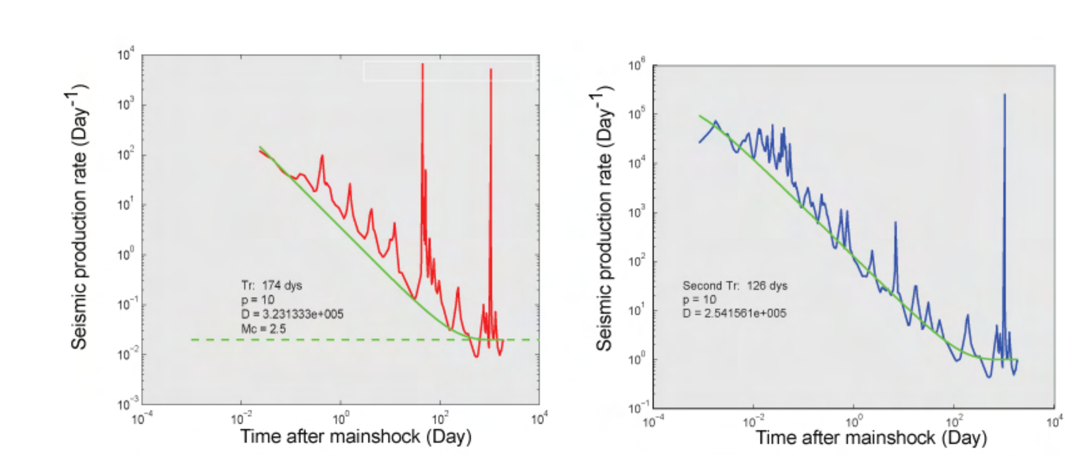


Fig. 9 Modeling result of the M=6.2 earthquake sequence. Left part shows the fitting result for the seismicity rate that is remotely affected by the *Ilan earthquake (Mw = 6.8)* offshore. Green line shows the fitting cruve. The relaxation time of its secondary aftershock is almost the same as its primary aftershock decay. In 2005, another earthquake (M=6) nearby also showed similar relaxation time.