Decay of aftershock density with distance indicates triggering by dynamic stress

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Kyohei Suzuki (M1)

Introduction

- Previous studies : Static stress changes trigger aftershocks .

- Recently studies : dynamic stresses changes may also trigger them （ seismic shaking ）.

- aftershock density decays with distance from the mainshock have found a range of functions.（power low)

Analyze(Data)

- 1984–2002 relocated Southern California catalogue.

(Shearer er al., 2005)

- M 2–6 mainshocks

divided

- M 2–4 mainshocks and M ≥2 aftershocks
- M 5–6 mainshocks and M ≥3 aftershocks

Mainshock and aftershock selection

- Earthquakes are used as mainshocks if they are separated from larger earthquakes by at least 100 km or by t_1 days if the larger earthquake comes first, and t_2 days if it comes after.
- t is the time after the mainshock for which we use aftershock data $t_1 \ll t < t_2$

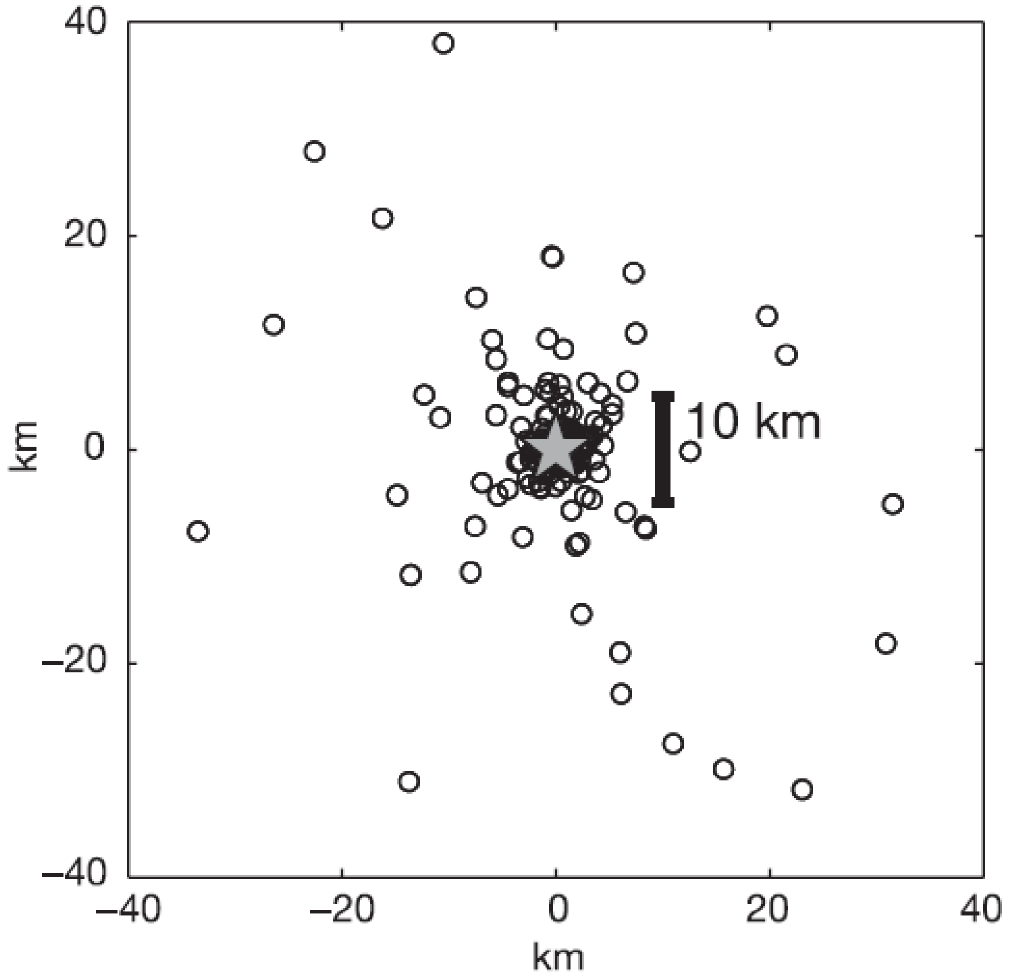
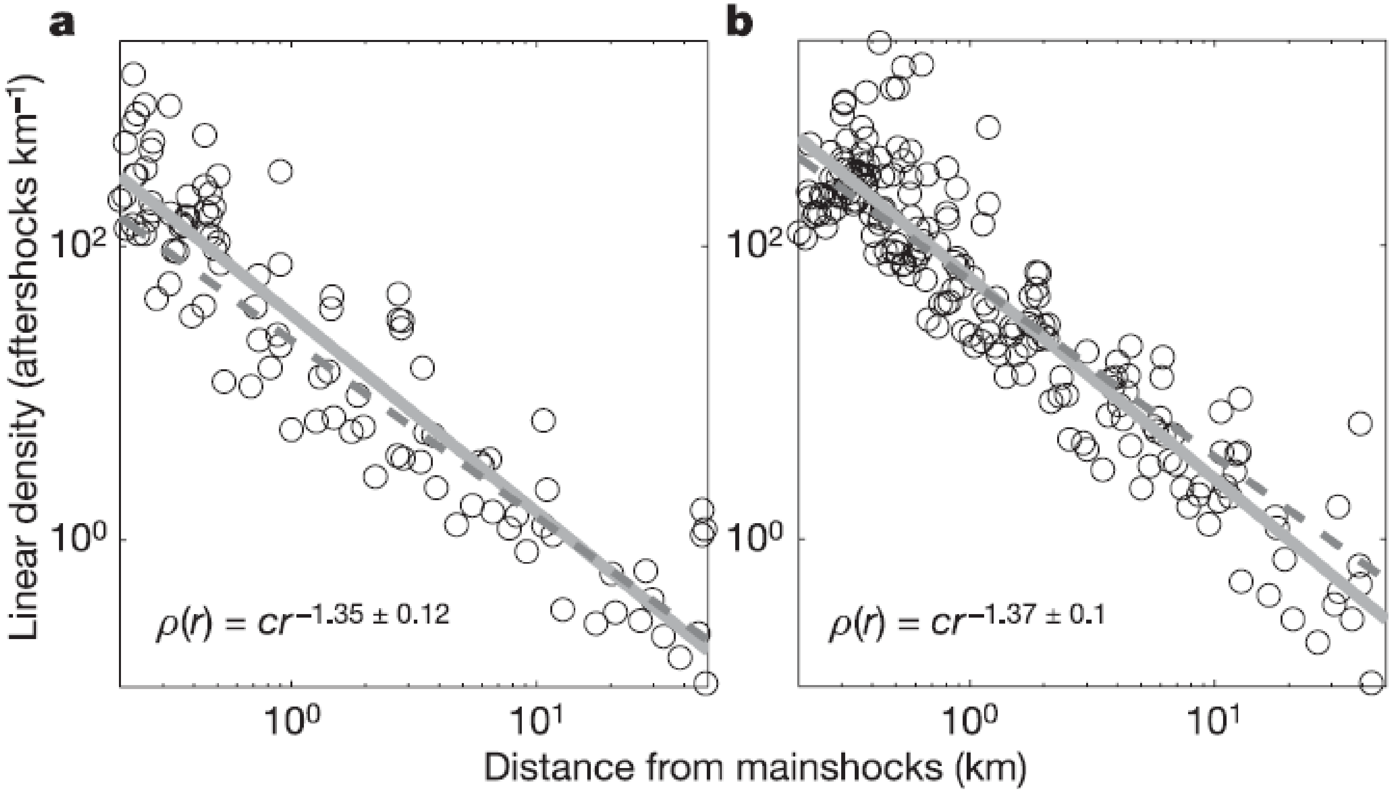


Figure 1 | Combined aftershocks of *M* = 3–4 mainshocks. To create a composite aftershock data set, we move all of the mainshocks to the origin in space and time and move their aftershocks with them. Data here are for the first 30 minutes of aftershocks of *M* = 3–4 mainshocks. The grey star gives the locations of the mainshocks, at the origin.

We can see decays with distance from the mainshock.

Result
(M 2–4 mainshocks)



- Point sources
- From 0.2 to 50 km, the data are well fitted by

$$\rho(\mathrm{r}) = \mathrm{c}r^{-n} \qquad (1)$$

(within 5 min)

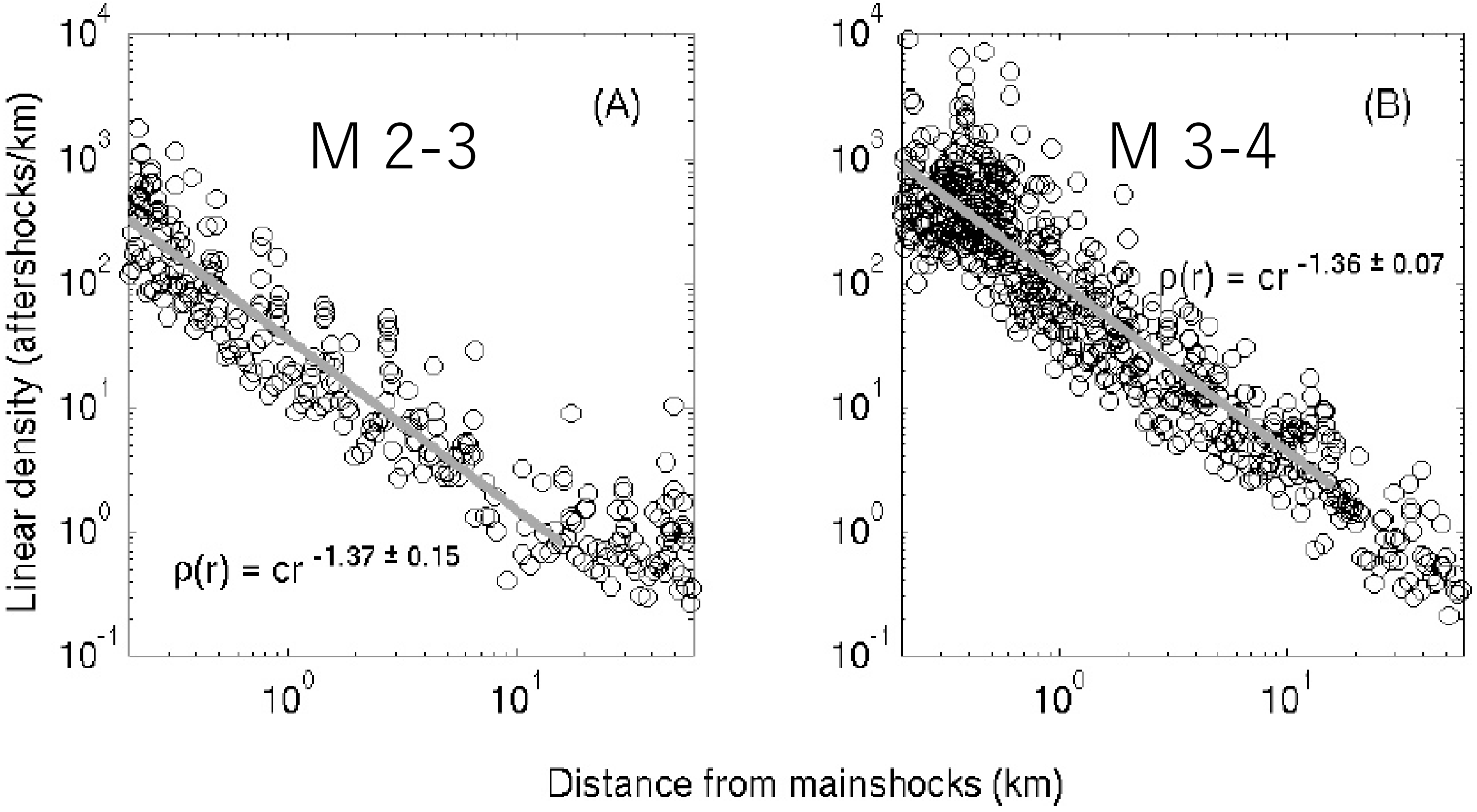
c : constant

$n = 1.37 \pm 0.1$

$for\ 3 \leq M < 4$

$n = 1.35 \pm 0.12$

$for\ 2 \leq M < 3$

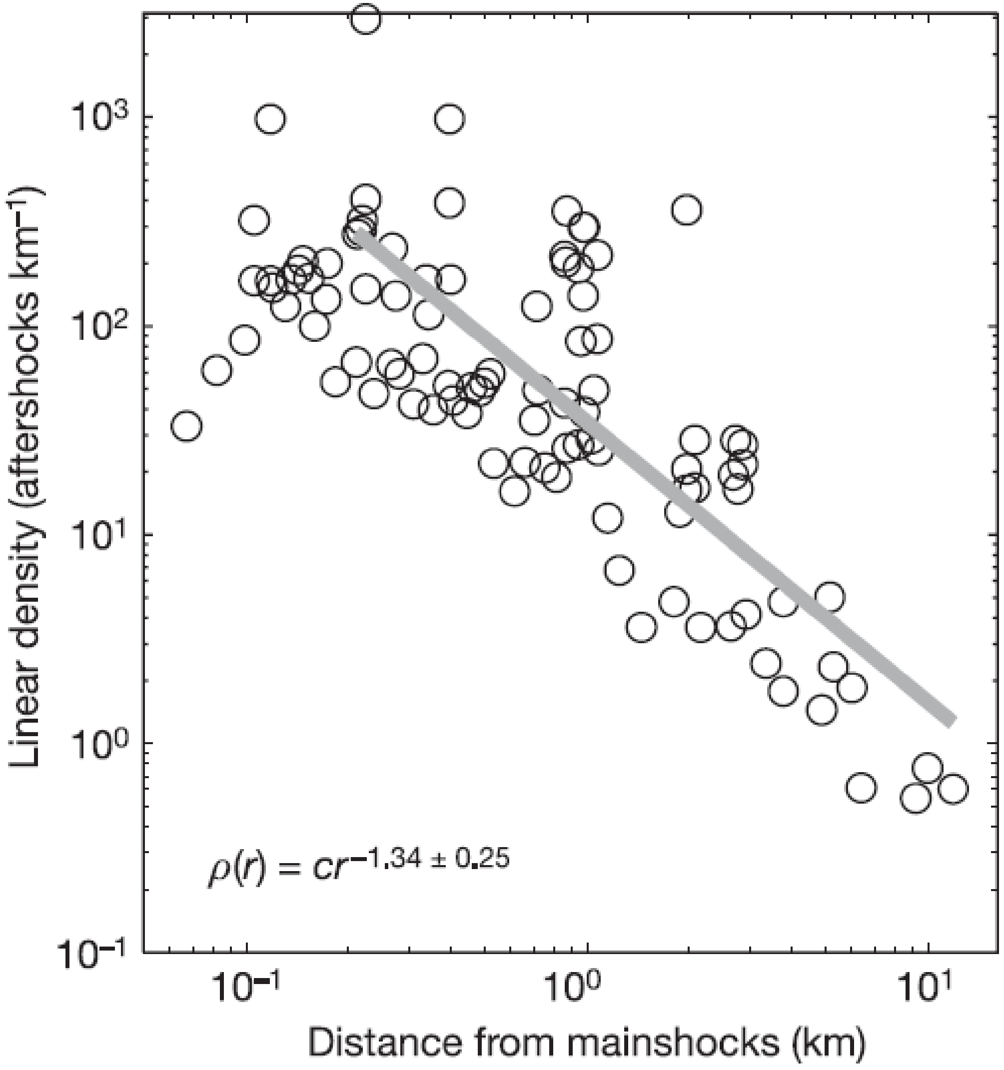


- We also check the applicability of equation (1) to longer times

- Within 30 minutes

- From 0.2 to 16 km, the data are fitted .

Result
(M 5–6 mainshocks)



within 2 days

- Harvard CMT focal mechanism solution
- Estimate fault plane
- recover an inverse power law from 0.2 km to 12 km from the closest point on the fault plane
- $n = 1.34 \pm 0.25$

- The consistent aftershock decay relationship observed from distances of 0.2 km to 50 km (from within 0.05 fault lengths of M 5 mainshocks to over 100 fault lengths of M 2–3 mainshocks)

- Static stresses decay rapidly.

- Triggering by static stress in the near field and dynamic stress in the far field would require a discontinuity in the aftershock decay.

- Only uniform triggering by dynamic stress matches the observation of a single, consistent decay that traverses a wide range of distances

We also find more model-dependent evidence that the number of aftershocks triggered varies linearly with dynamic stress change amplitude.

$$B(r) = c_1 r^{(D-1)} \quad (3)$$

- B(r) is the background seismicity per kilometre per unit time as a function of distance from the mainshock.
- This function describes points randomly scattered on a structure with effective dimension D.

be separated into geometric and physical terms

$$\rho(r) = \frac{N_{\mathrm{aft}}}{\Delta r} = \frac{N_{\mathrm{hyp}}}{\Delta r} \times \frac{N_{\mathrm{aft}}}{N_{\mathrm{hyp}}} = cr^{-1.4} \tag{4}$$

be substituted for the geometric term

$$\rho(r) = c_1 r^{D-1} c_3 r^{m} = cr^{-1.4} \tag{5}$$

- We find a better fit with D = 1 than with D = 2 or 3; that is, the linear density is independent of distance .

- earthquakes concentrate on planar faults, whose width is also limited by the seismogenic depth. At distances longer than ,10–20 km, effective D for earthquakes randomly scattered on a fault tends towards 1.

In summary

- the decay of aftershock linear density with distance from M 2–6 mainshocks is well fitted by an inverse power law.
- If the linear density of faults is independent of distance , then the data indicate that the probability of triggering an aftershock is directly proportional to the amplitude of seismic shaking.
- The similarity of aftershock decay from distances of 0.05 to over 100 fault lengths implies a single physical triggering mechanism, and dynamic stress change is the only plausible agent over most of this range.