Evidence that Stress Amplitude Does not Affect the Temporal Distribution of Aftershocks

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Aftershock triggering is often modeled as the “clock advance” of faults

There are two ways this clock advance could occur -

1. Harold Lloyd Model

Harold tries to apply a clock advance

Two possible outcomes of Harold-applied stress

1) The clock is too stiff/Harold is too light → no clock advance

2) The hand gives way → maximum clock advance

- If Harold is heavier, a clock advance is more likely
- But Harold's weight ≠ clock advance size

2. Mouse Nudge Model

- A clock advance will always occur
- Clock advance $\propto$ stress applied by mouse

Both the "Harold Lloyd" and "mouse nudge" models have been proposed for aftershocks

- **Mouse nudge models** = Accelerating Failure [**Rate & State friction**, (*Dieterich*, 1994); **Subcritical Crack Growth** (*Atkinson*, 1979; *Das and Scholz*, 1981, and others)]
- All faults are affected by stress change **& effect is proportional to stress change amplitude**

- **Harold Lloyd models** = Stochastic models (*Kagan*,1982; **ETAS**, *Ogata* 1998, and others)
- At lower stress changes there are fewer aftershocks, **but all aftershocks follow the same decay rate**

Which model is correct ?

Aftershock Data

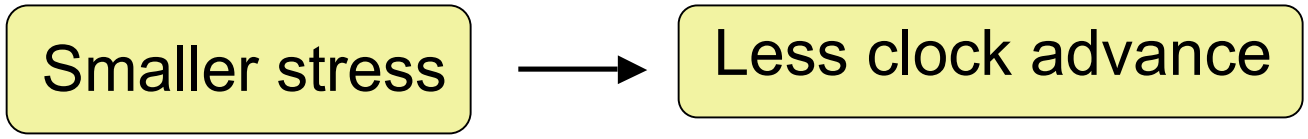
- 2 days of M≥3 aftershocks of 33 M 5-6 California mainshocks that were not preceded by a larger earthquake within 30 days/500 km
- 30 days of M≥3 aftershocks of the M 7.3 1992 Landers earthquake

Stress Change Data

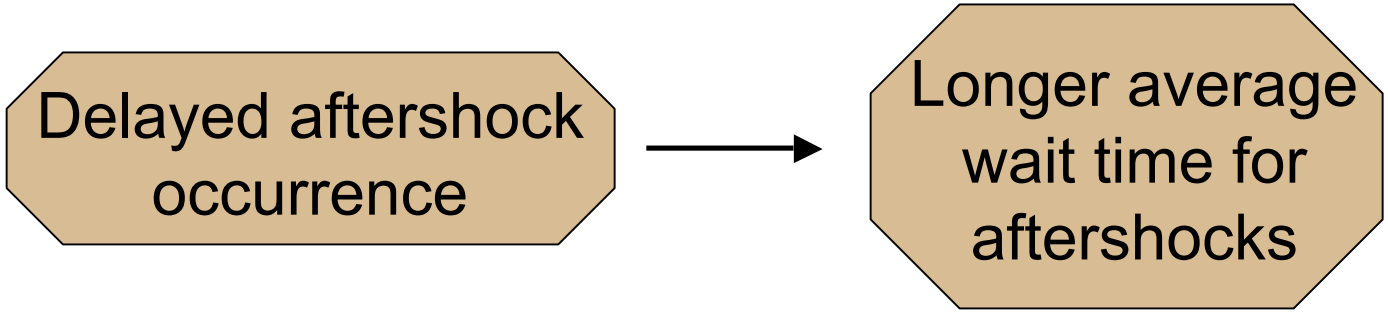
- Distance from the fault is used as a proxy for stress change amplitude

Test #1: Does mean aftershock time vary with stress change?

IF

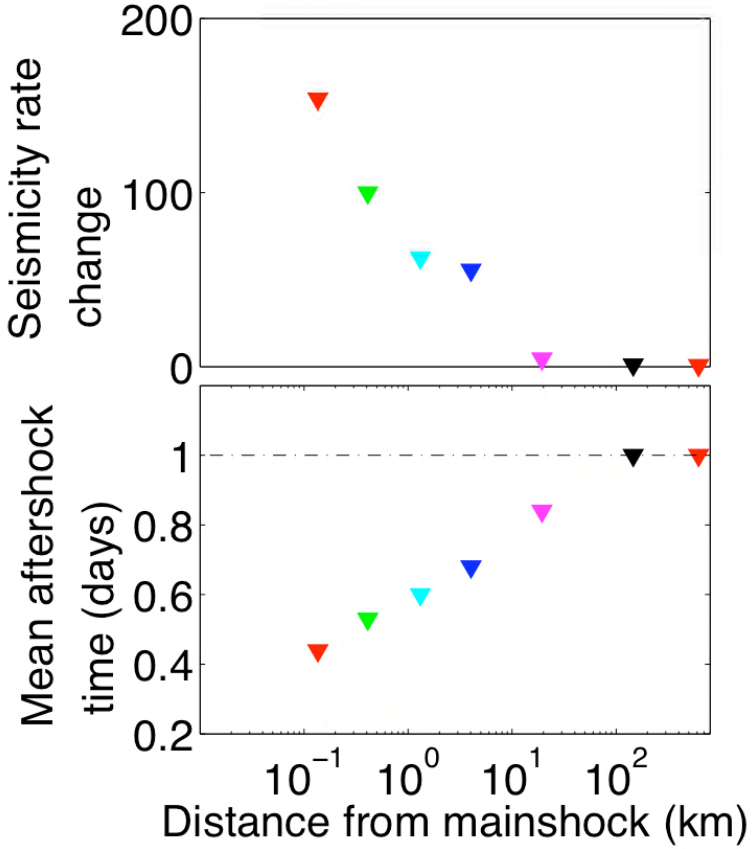


THEN

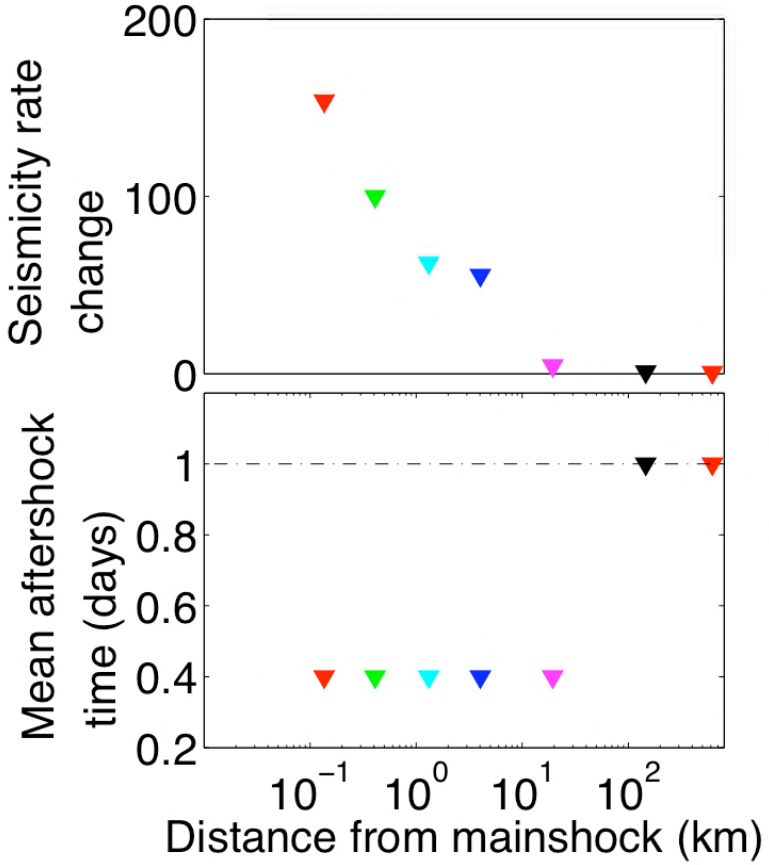


Test #1: Does mean aftershock time vary with stress change?

Expectation for mouse nudge model

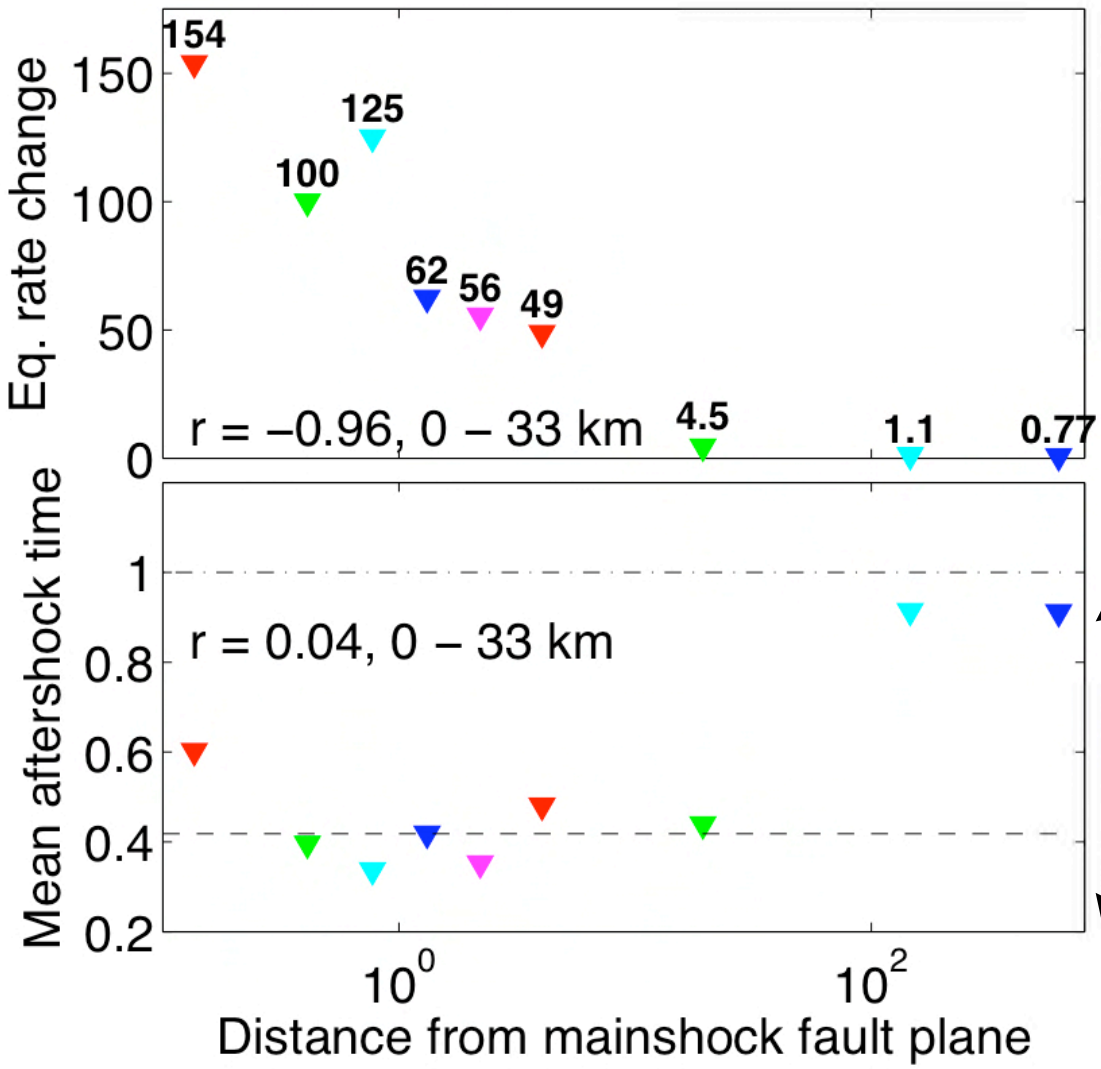


Expectation for Harold Lloyd model



Aftershocks measured over first 2 days of sequences

M 5 - 6 mainshocks: Average aftershock time does not vary with stress change

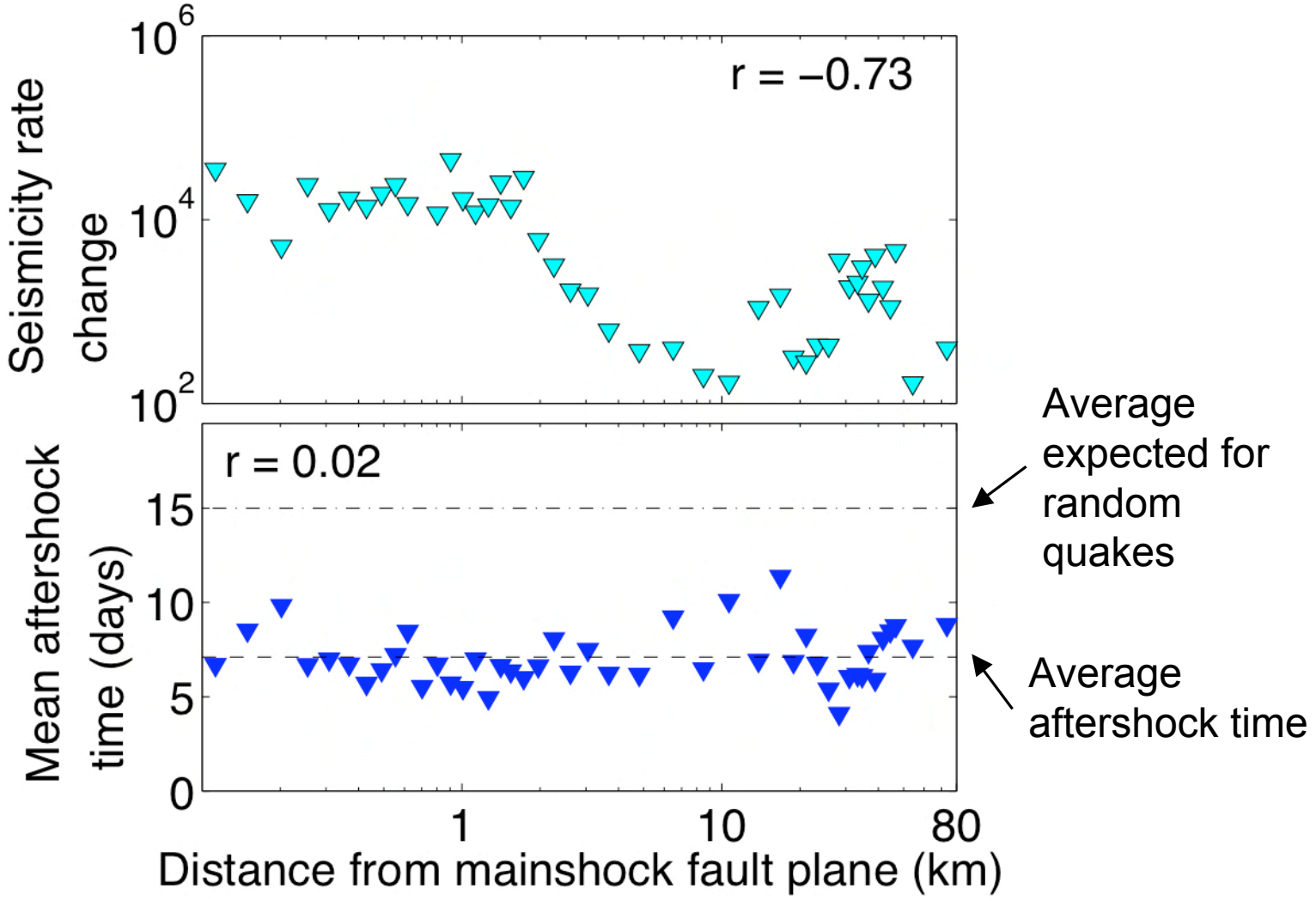


Average expected for random quakes

Average aftershock time, 0-33 km

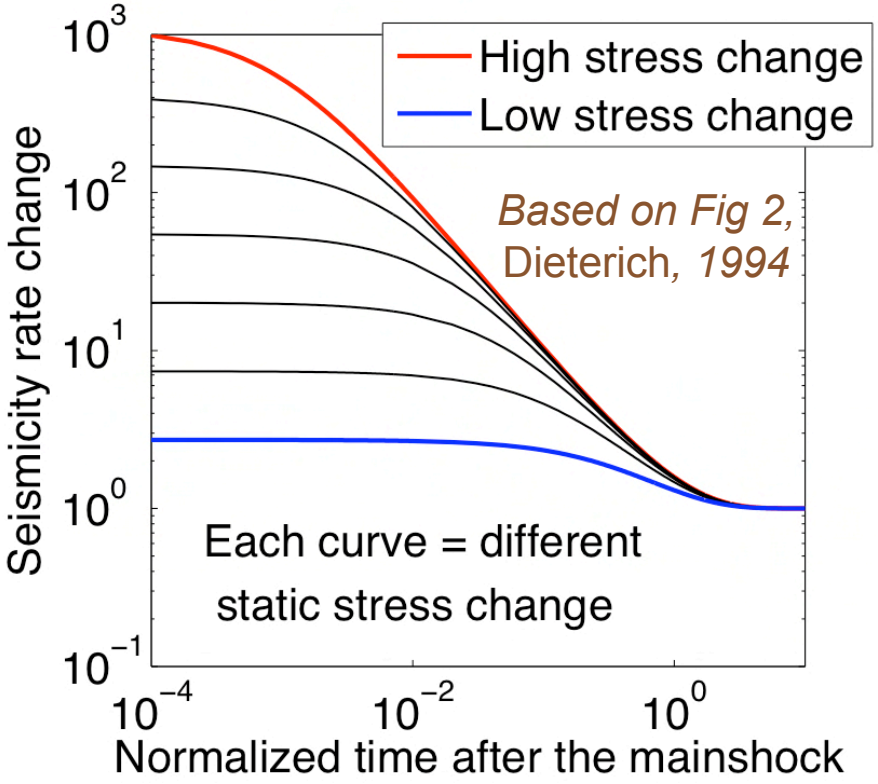
Aftershocks measured over first 2 days of sequences

M 7.3 Landers earthquake: Average aftershock time is independent of stress change

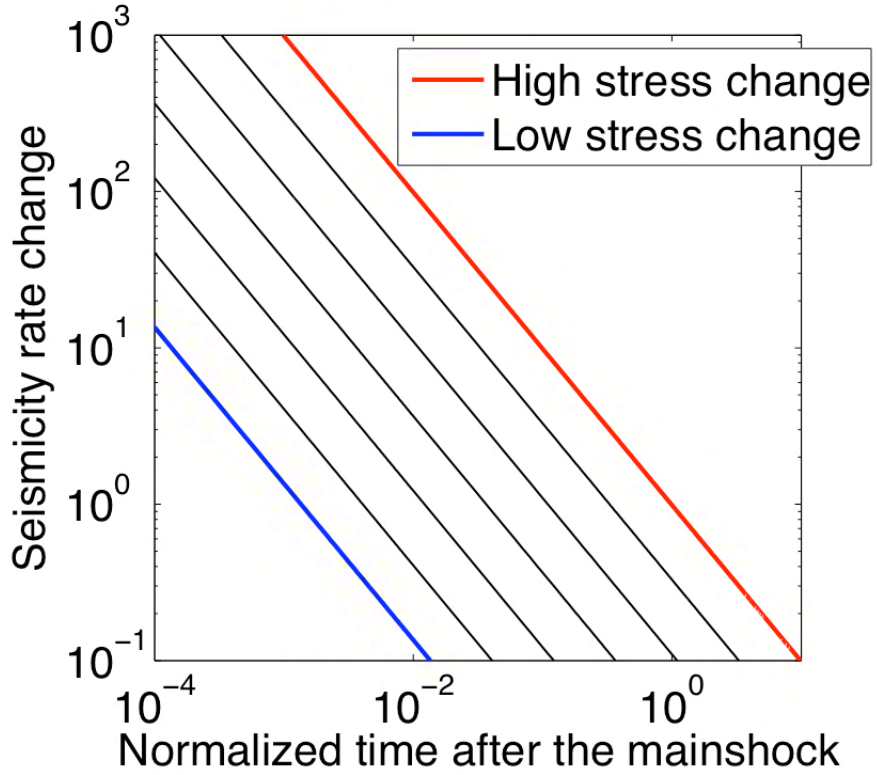


Aftershocks measured over first 30 days of sequence

Test 2a: Does the seismicity rate change decay vary with distance from the fault?

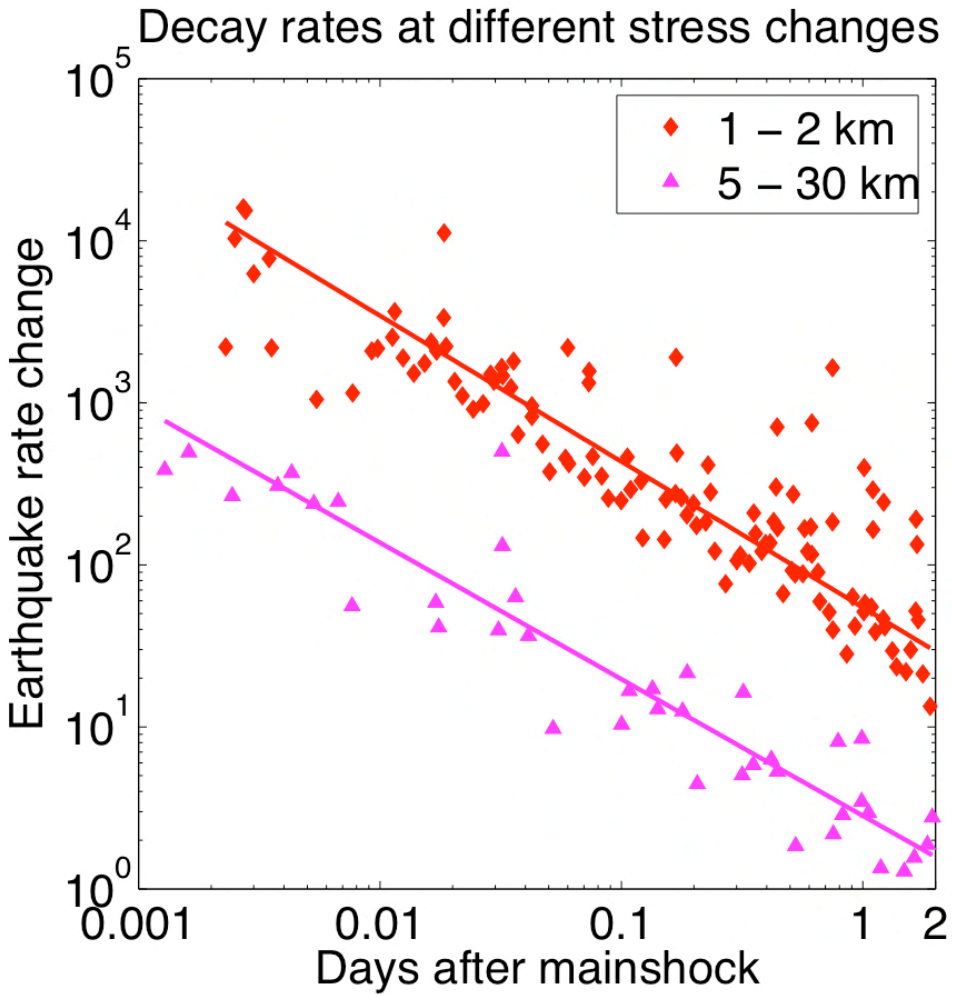


"Mouse nudge" prediction
Fewer rapid aftershocks at lower stress change



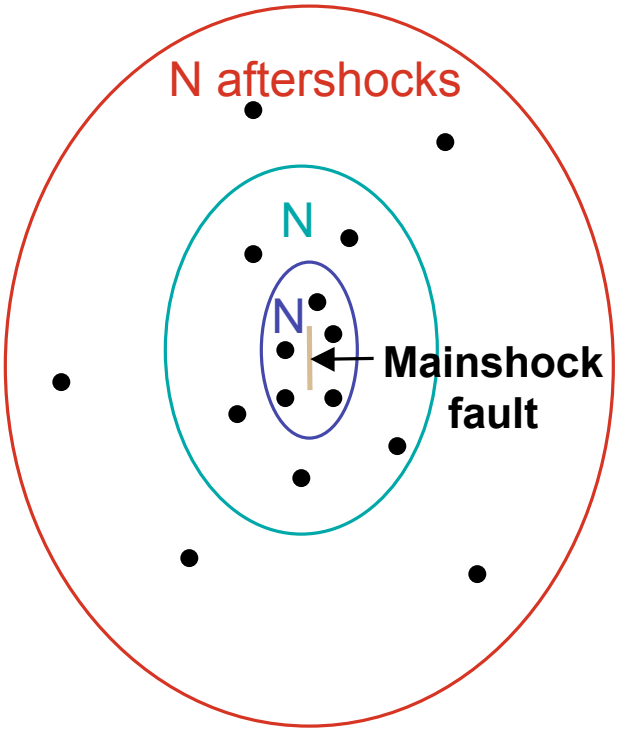
"Harold Lloyd" prediction Decay rate the same at all stress changes

M 5 - 6 mainshocks: Seismicity rate change decay does not depend on distance



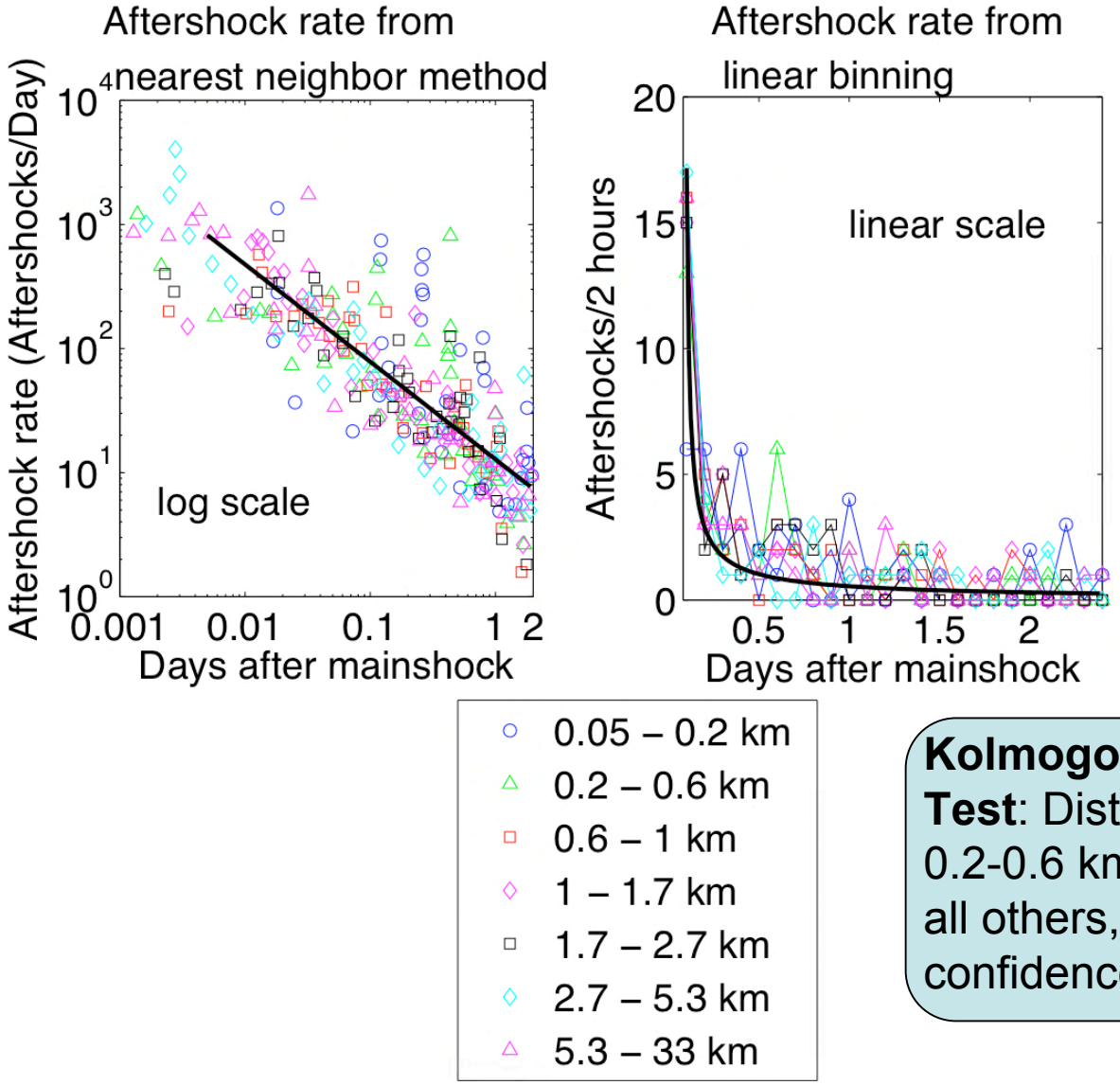
Agrees with results of *Jones and Hauksson* (1998) for Landers

Test 2b: Does the distribution of raw aftershock times vary with distance?



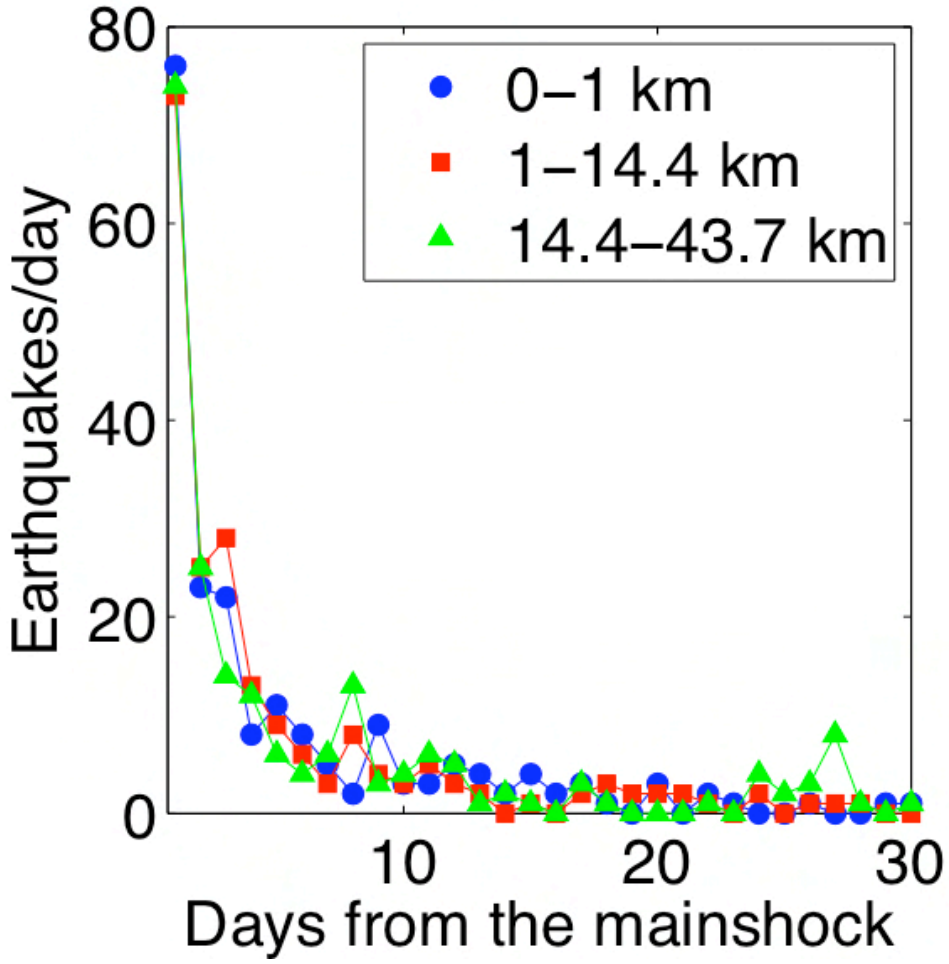
- We draw annuli such that there are the same number (**N**) earthquakes in each one
- If the distribution of aftershock times does not vary with distance (Harold Lloyd model), **curves of time vs. aftershocks/time should be the same in each annulus**

M 5 - 6 mainshocks: Groups of 40 aftershocks at different distances show the same decay



Kolmogorov-Smirnoff Test: Distribution from 0.2-0.6 km agrees with all others, 95% confidence

Landers mainshock: Groups of 200 aftershocks at different distances show the same number of aftershocks/day



Kolmogorov Smirnoff Test: All distributions similar at 95% confidence

Conclusions

- The temporal distribution of aftershocks at all distances/stress changes is the same
- This implies that aftershock clock advance is independent of stress change amplitude
- This supports stochastic aftershock models, indicates reassessment of accelerating failure models