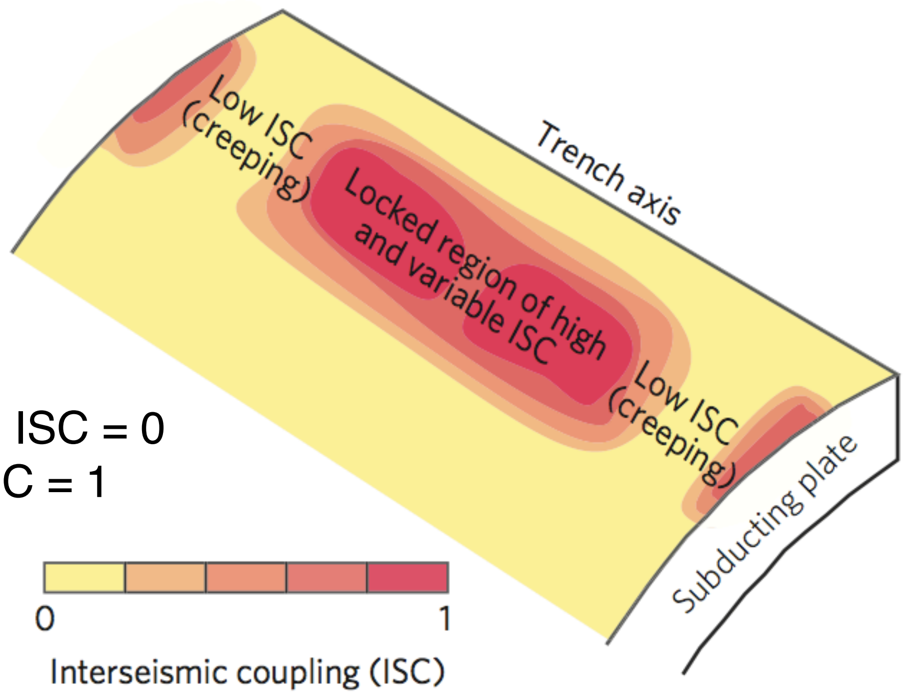
Subduction zone fault surface, showing locked and creeping areas

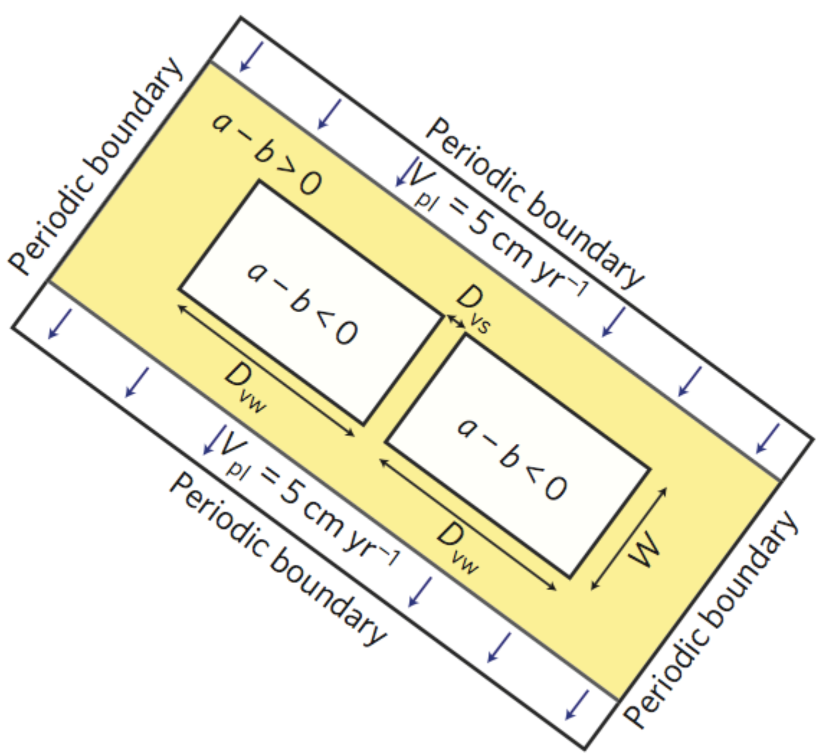
a



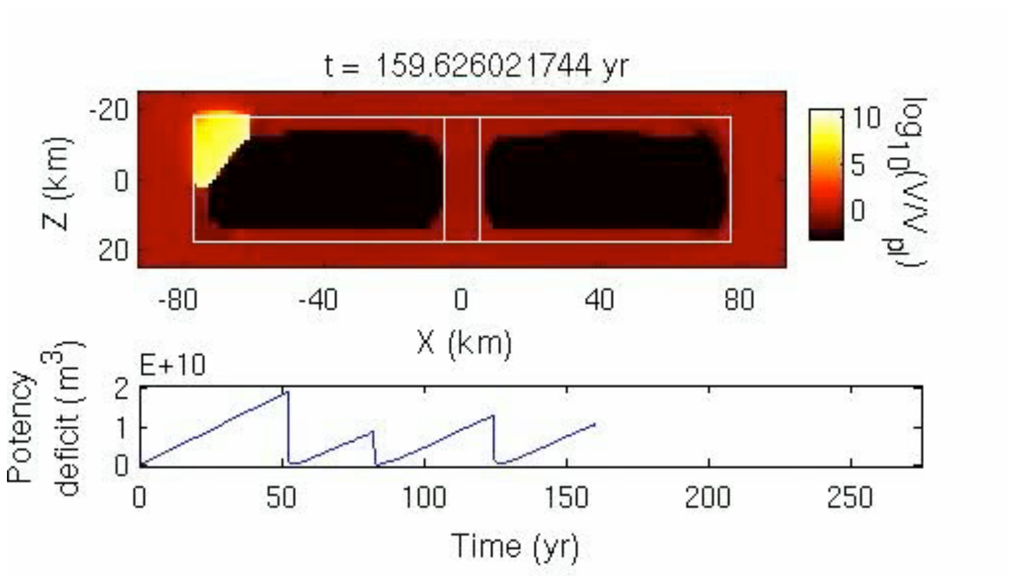
- creeping: ISC = 0
- locked: ISC = 1

Model of a subduction zone fault surface, with velocity-weakening and velocity-strengthening areas

c

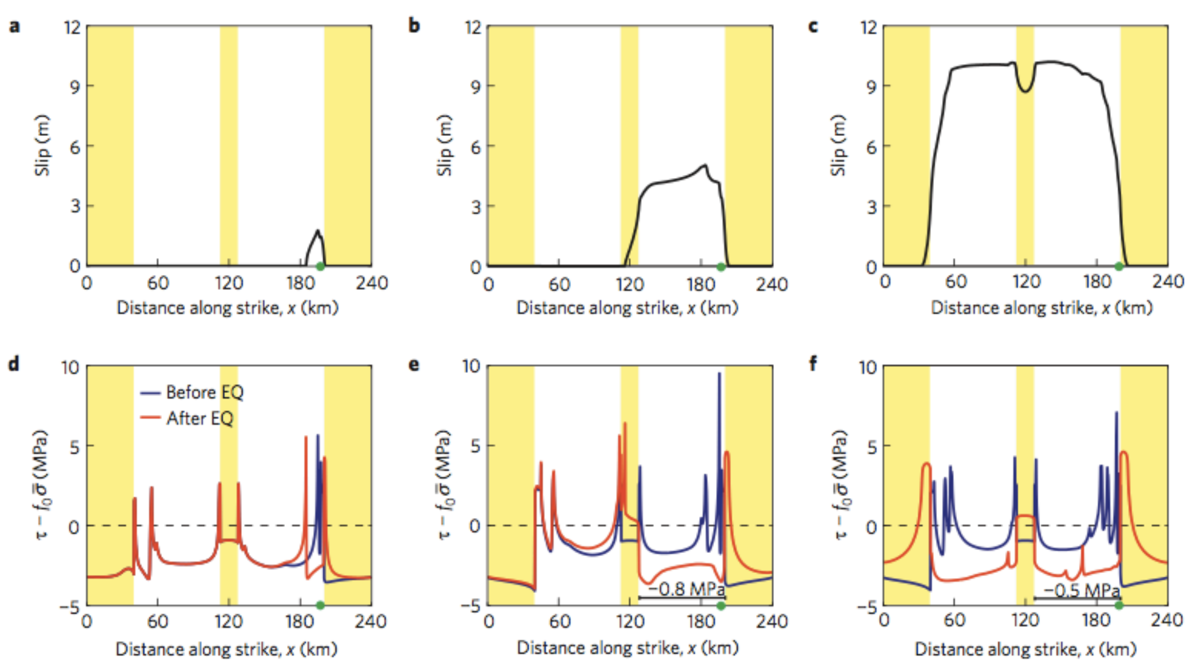


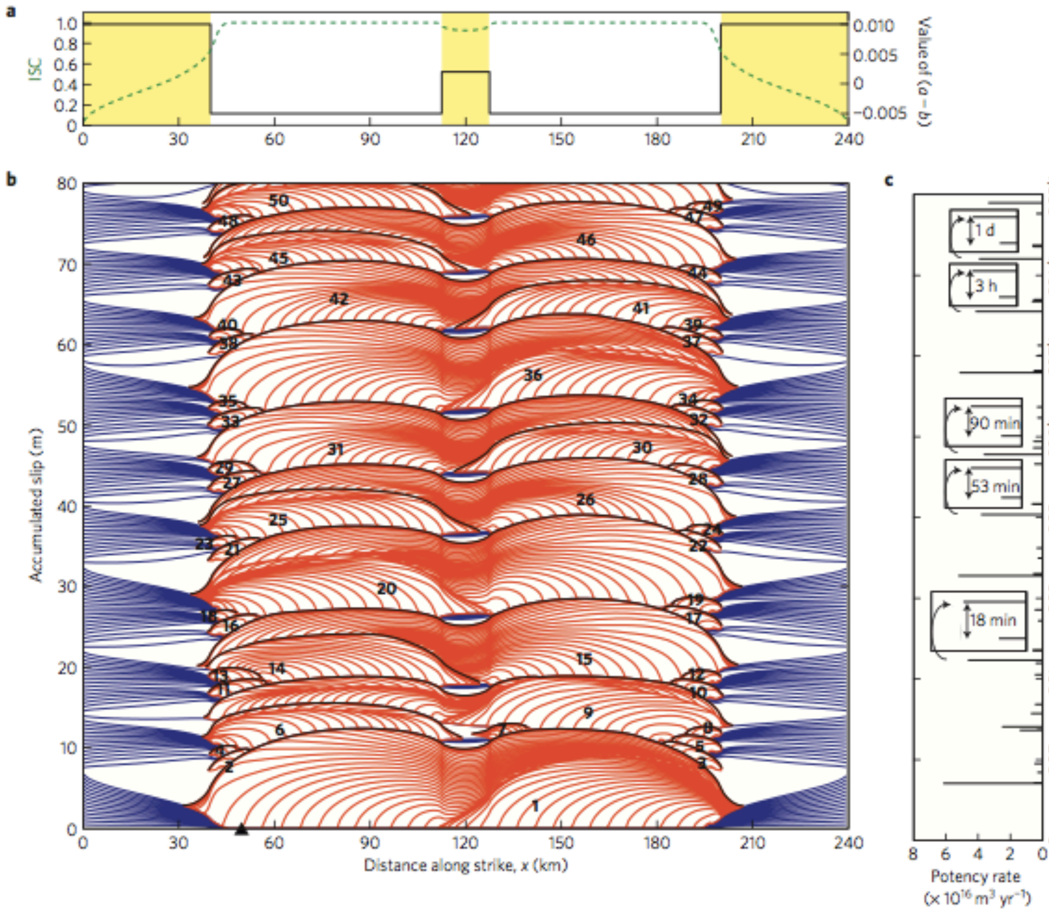
Movie showing modeled earthquakes and interseismic creep over many earthquake cycles

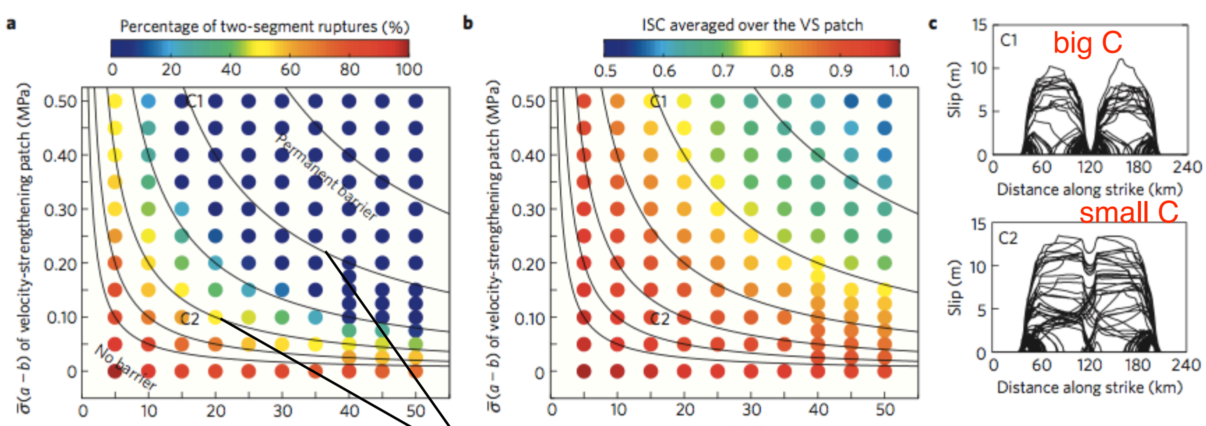


seismic potency is just seismic moment / shear modulus (= slip times area)

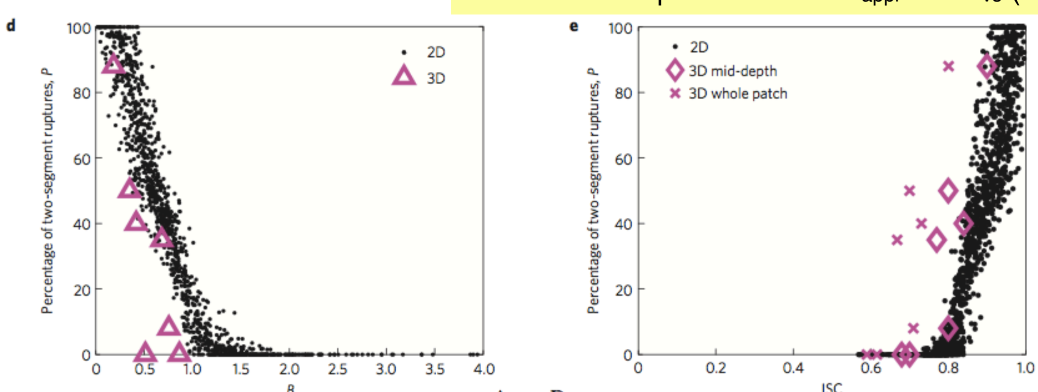
Small and large earthquakes. top row = slip distribution, bottom row = corresponding pre-and post-quake stress







contours are equal values of $C_{appr} = 20\sigma_{vs}\,(a_{vs} - b_{vs})D_{vs}$.



B is “barrier efficiency”

$$B = \frac{\Delta\tau_{prop} D_{vs}}{\beta \Delta\tau_{vw} D_{vw}}$$

Upshot: by monitoring seismic coupling between earthquakes (via GPS for example) the future large slip patches might be delineated.

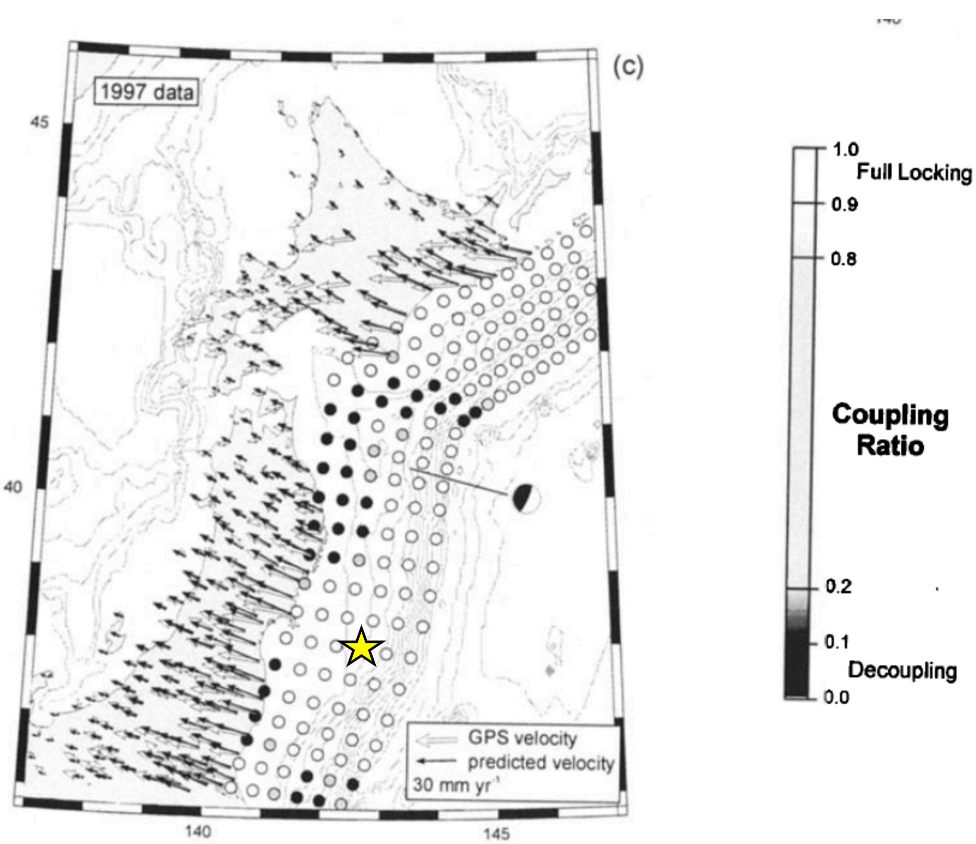
example:

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 105, NO. B6, PAGES 13,159–13,177, JUNE 10, 2000

Full interseismic locking of the Nankai and Japan-west Kurile subduction zones: An analysis of uniform elastic strain accumulation in Japan constrained by permanent GPS

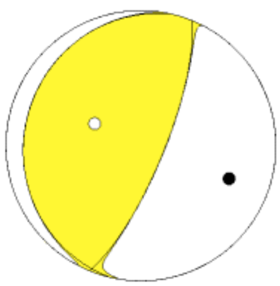
Stéphane Mazzotti,[1] Xavier Le Pichon,[2] and Pierre Henry
Laboratoire de Géologie, Ecole Normale Supérieure, CNRS UMR 8538, Paris

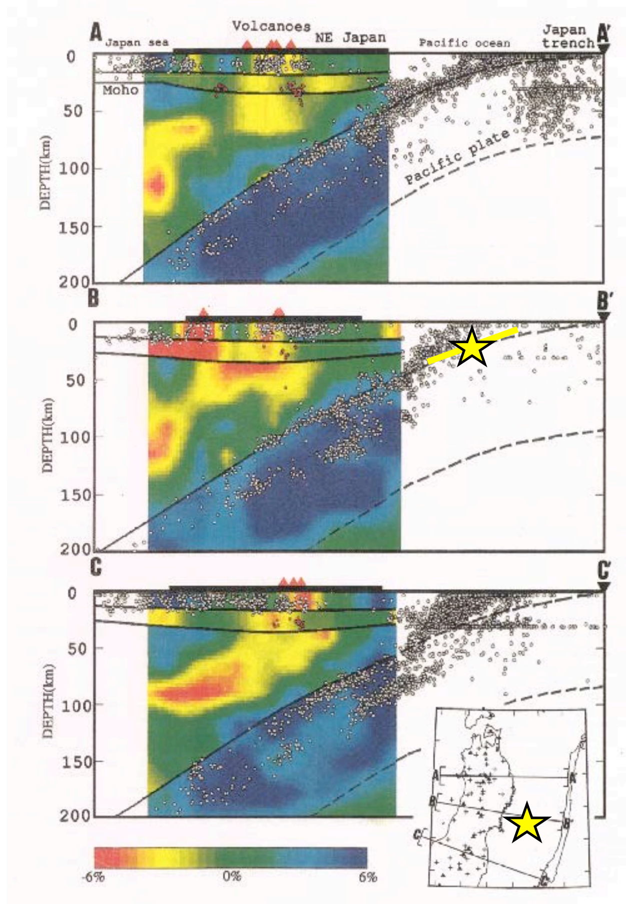
Shin-Ichi Miyazaki
Geographical Survey Institute, Tsukuba, Japan



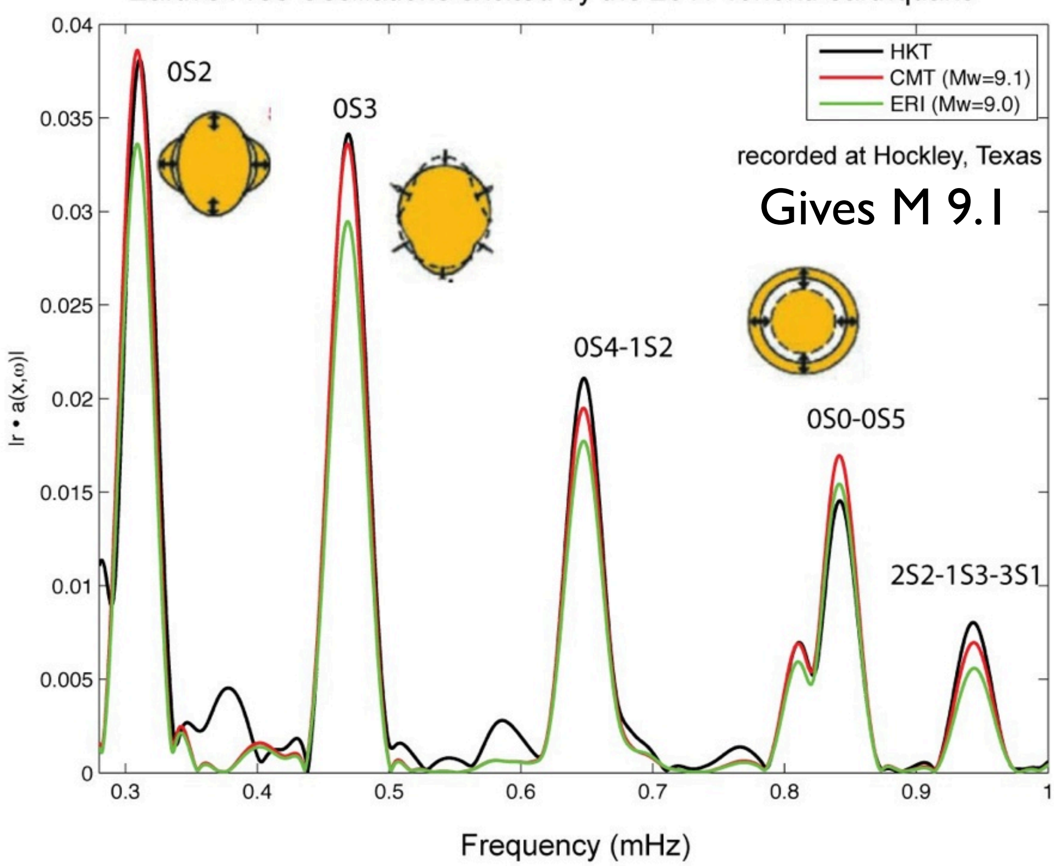
```
USGS/WPHASE CENTROID MOMENT TENSOR
11/03/11 05:46:23.00
Centroid:     38.321   142.969
Depth  24              No. of sta:256
Moment Tensor;     Scale 10**22 Nm
  Mrr= 1.82           Mtt=-0.13
  Mpp=-1.69           Mrt= 1.34
  Mrp= 3.17           Mtp=-0.56
 Principal axes:
  T  Val=  3.88   Plg=59   Azm=295
  N     =  0.03     2       201
  P     = -3.92    30       110

Best Double Couple:Mo=3.9*10**22
 NP1:Strike=193 Dip=14 Slip=  81
 NP2:        22     76        92
```

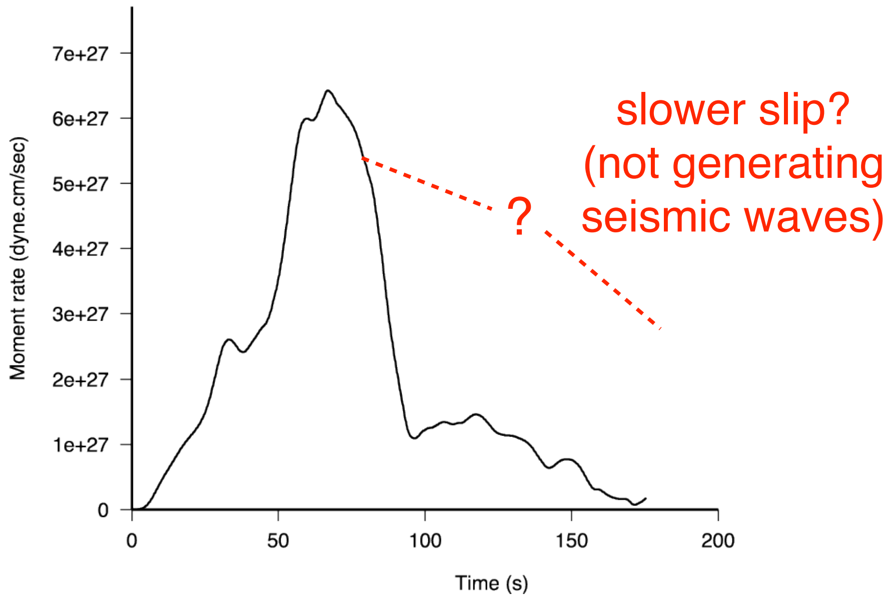


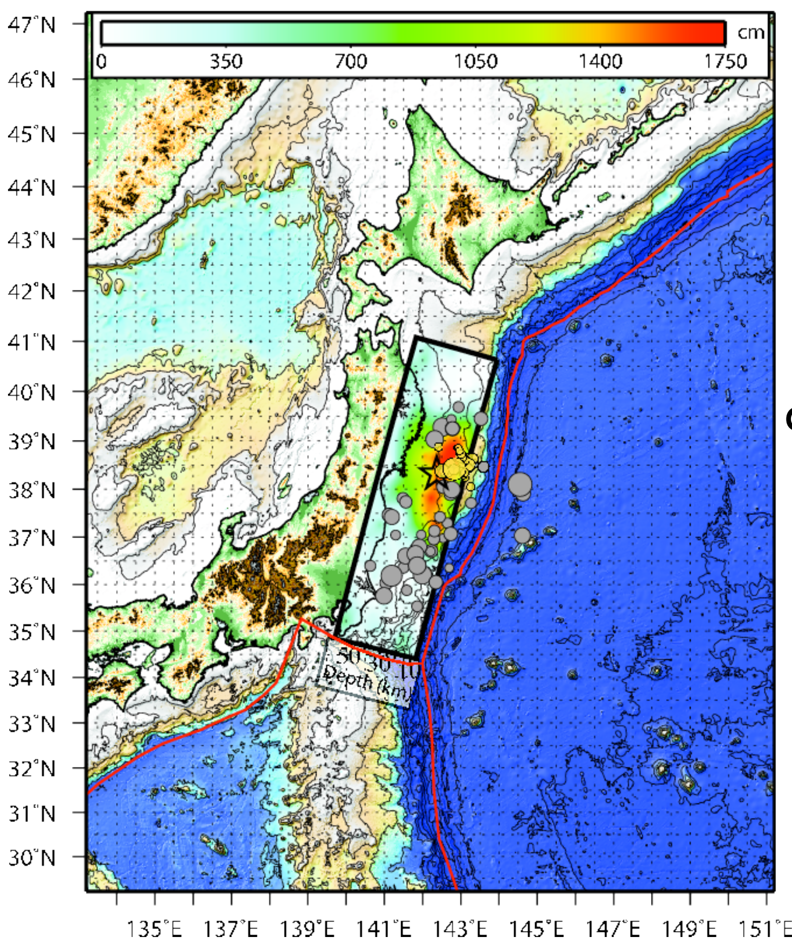


Earth's Free Oscillations excited by the 2011 Tohoku earthquake



Most fault slip happened in 1st 100 seconds, though this estimate probably missed a lot (slower slip)

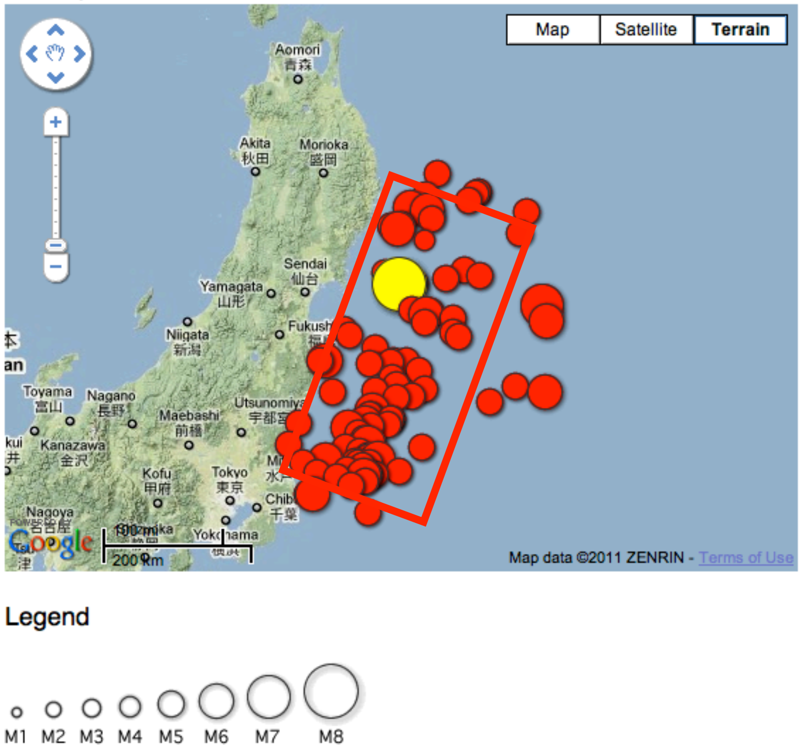




Distribution of coseismic slip and aftershocks

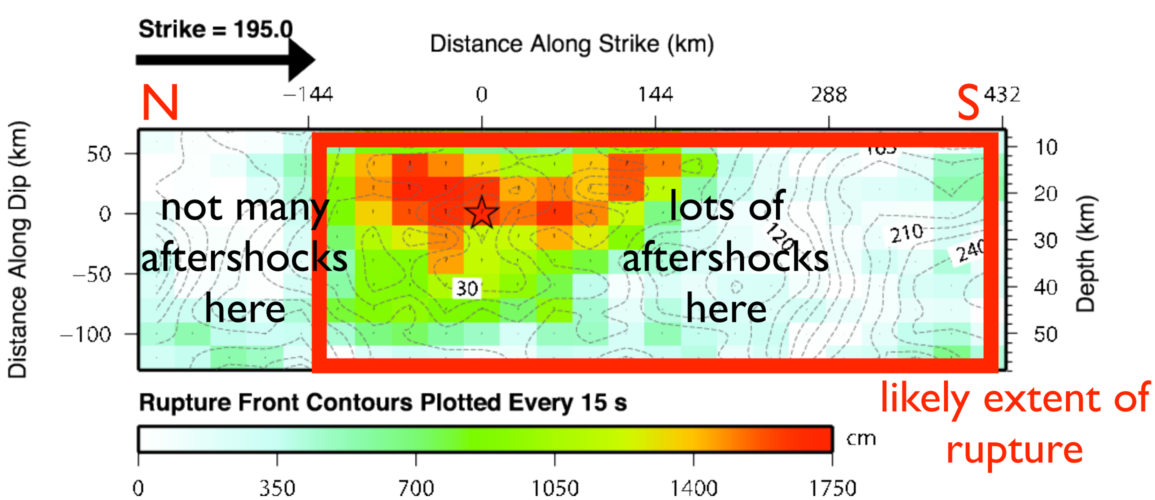
Aftershock Map - Mainshock and 91 Aftershocks

Last Updated: 11 March 2011, 18:11:03 UTC



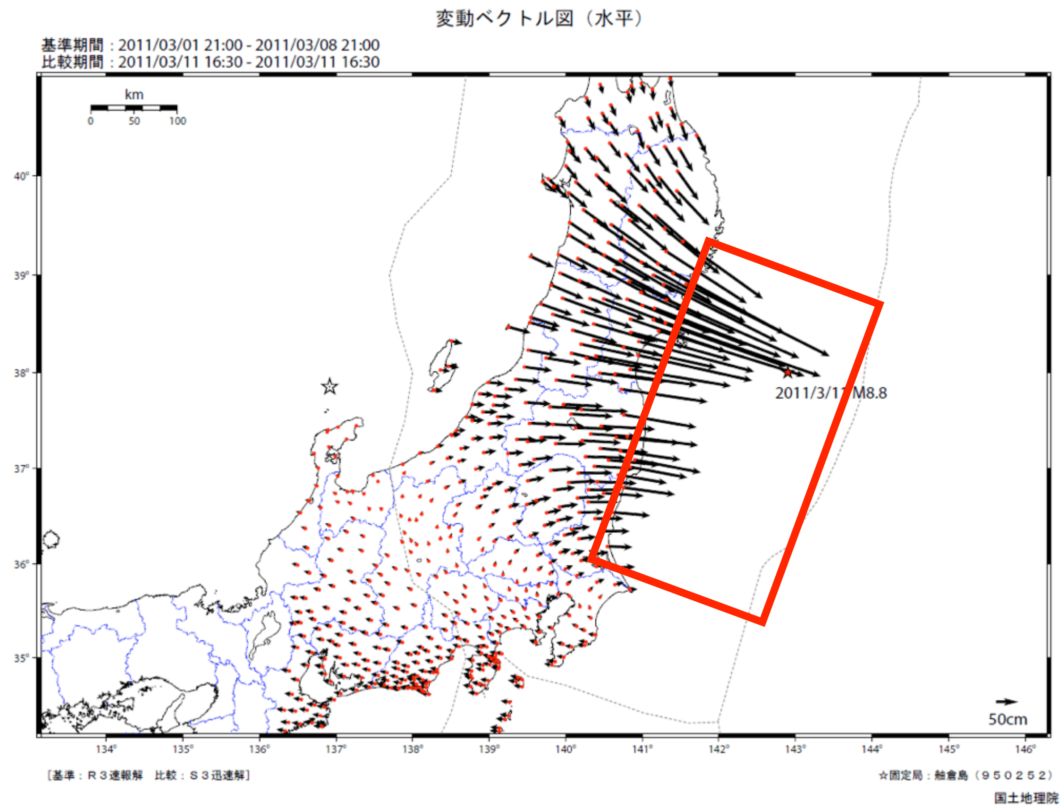
USGS

Fault slip estimated from modeling surface waves

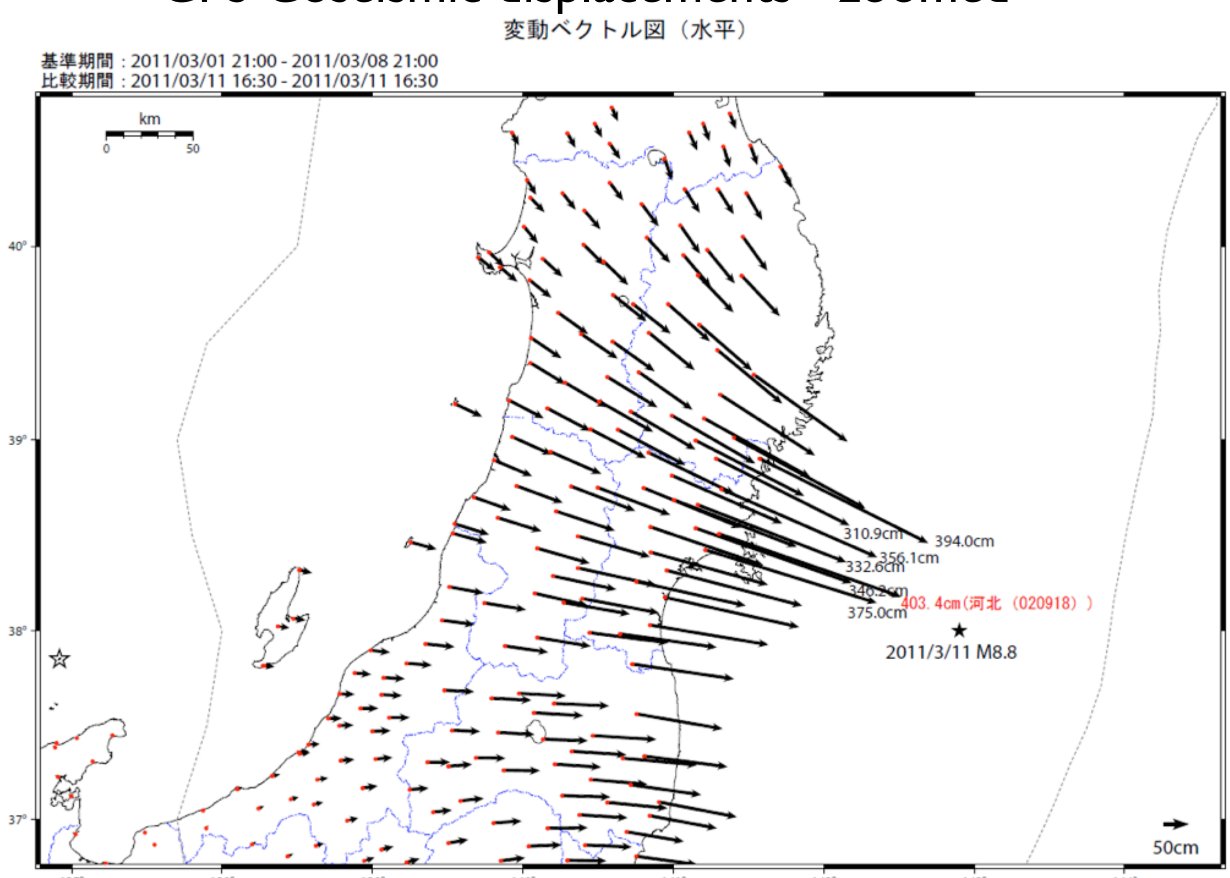


USGS
(Gavin Hayes)

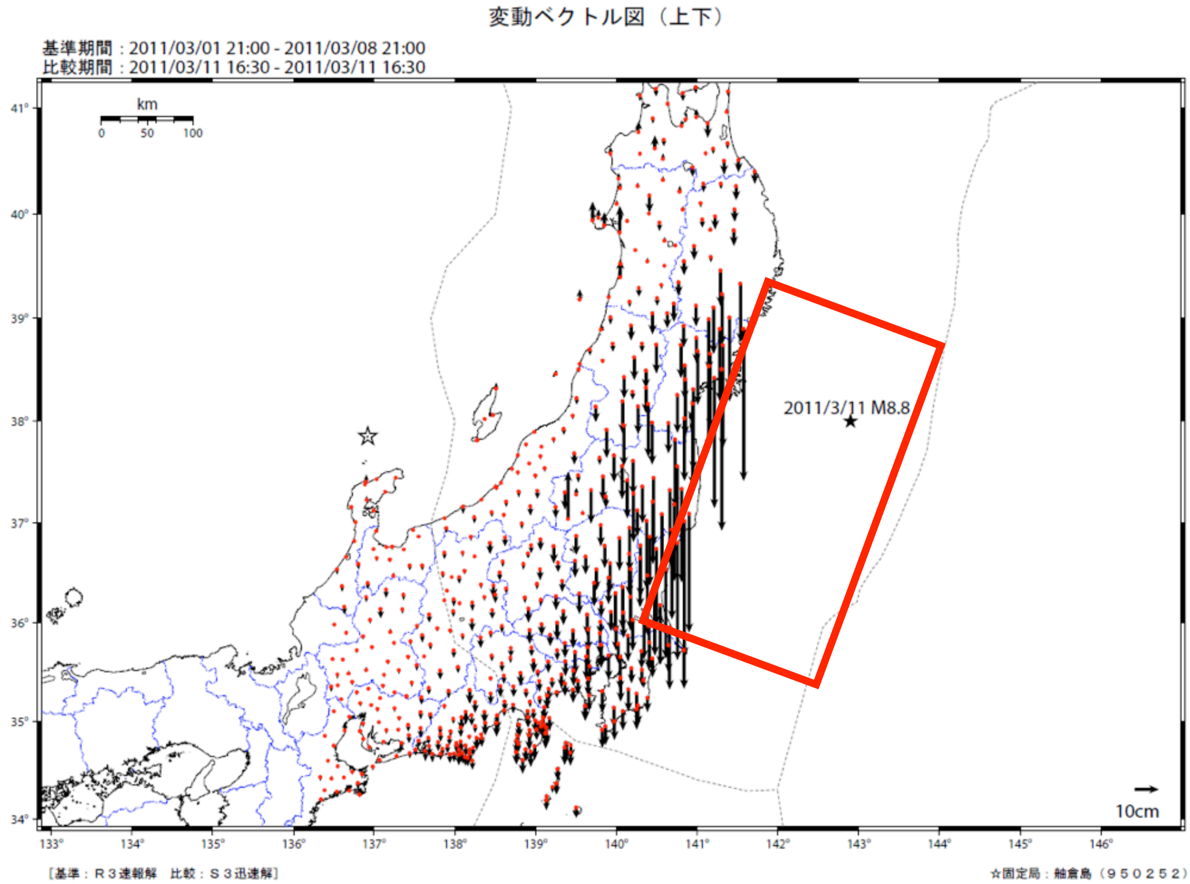
GPS Coseismic displacements



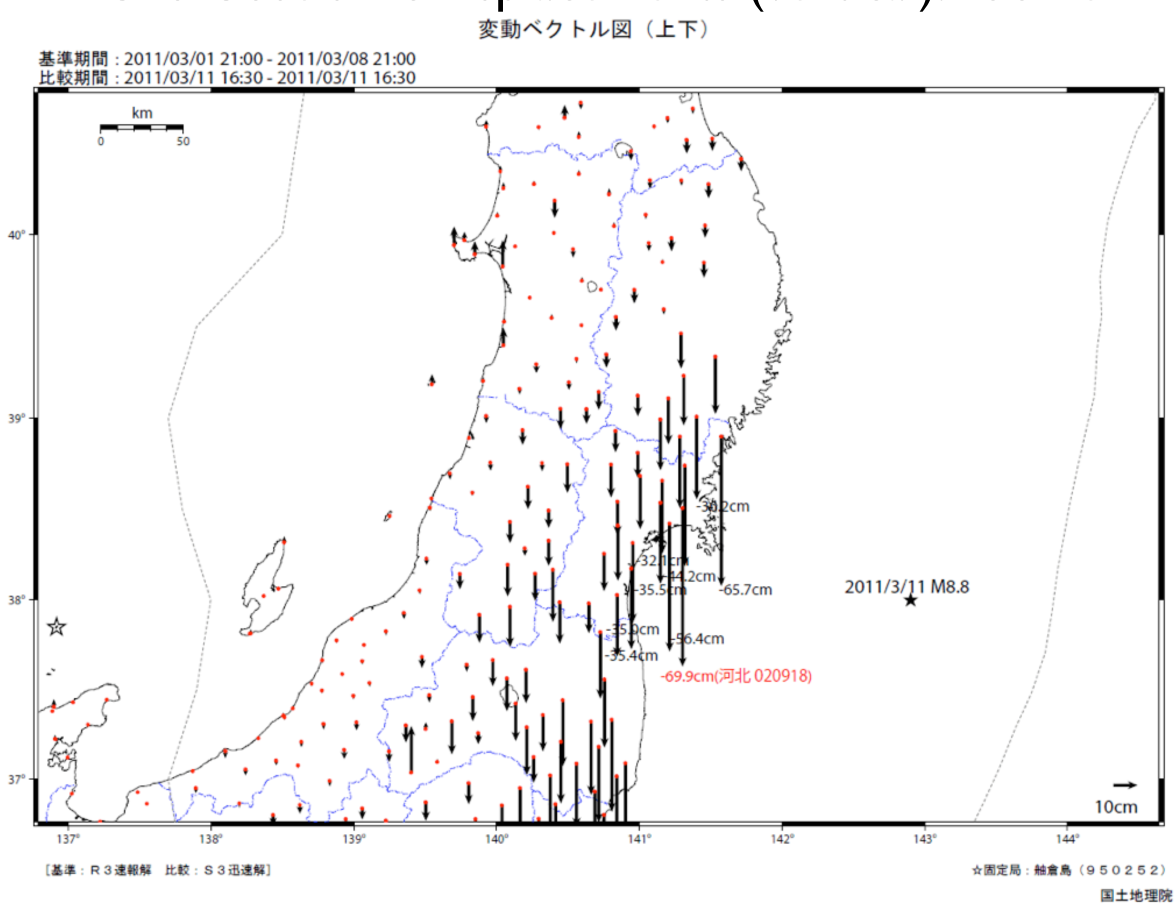
GPS Coseismic displacements - zoomed



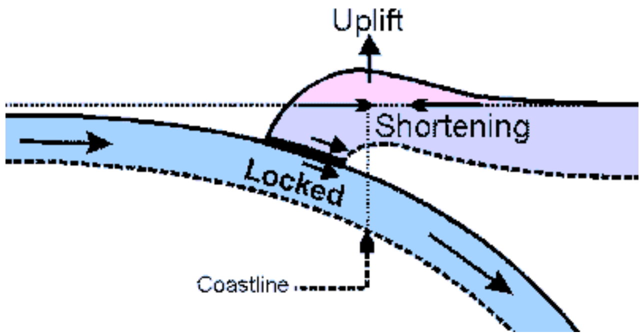
GPS Coseismic displacements (vertical)



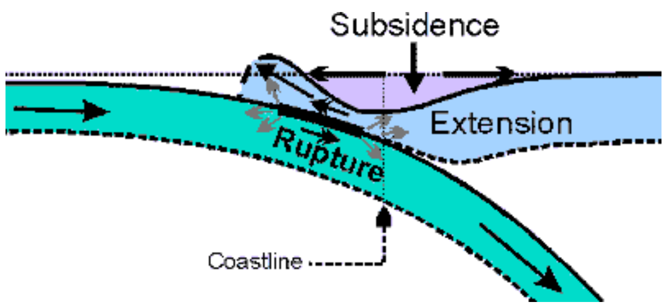
GPS Coseismic displacements (vertical): zoomed



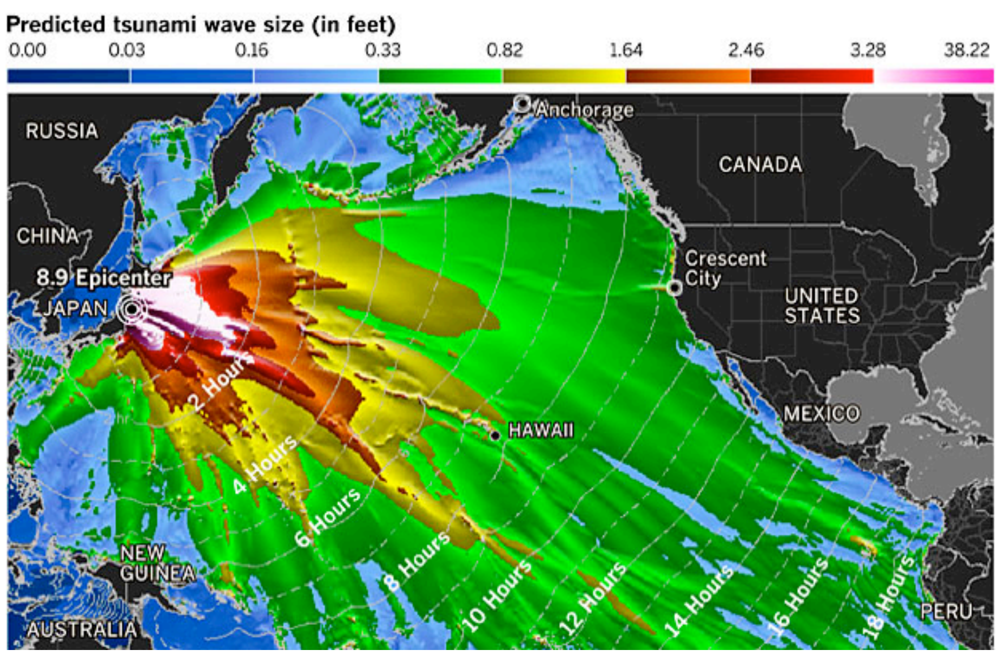
Subduction zone fault earthquake cycle



interseismic



coseismic

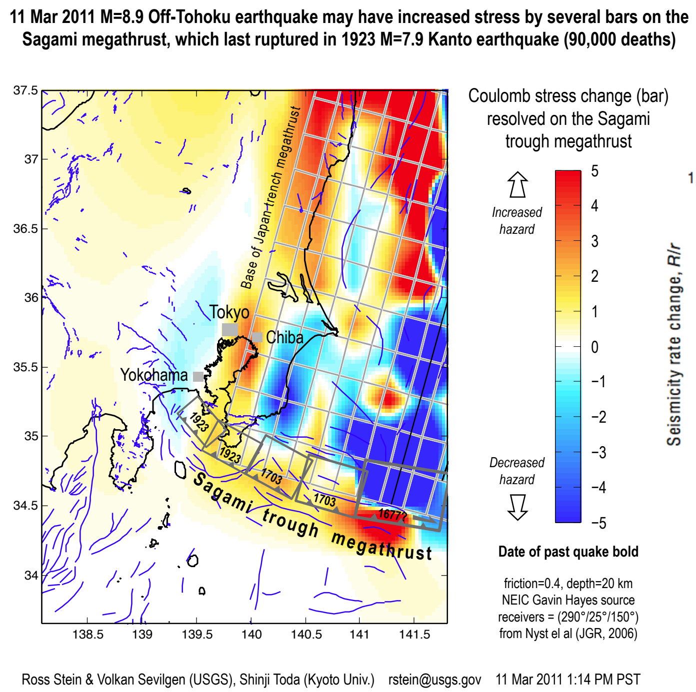


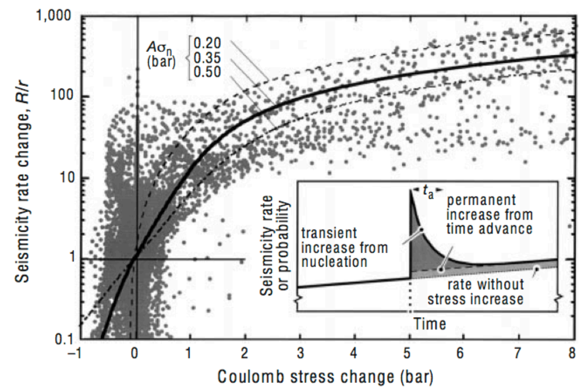
Tsunami: Much of Crescent City harbor destroyed; 4 people swept into sea, 1 feared dead [LA Times]

Waves at Crescent City = 2 m high

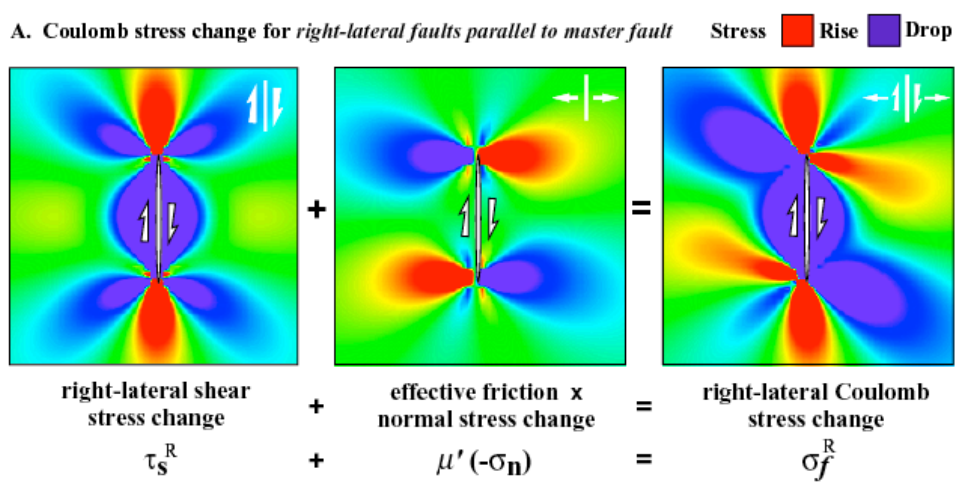
Coulomb stress change resolved onto Sagami thrust fault (from Ross Stein)

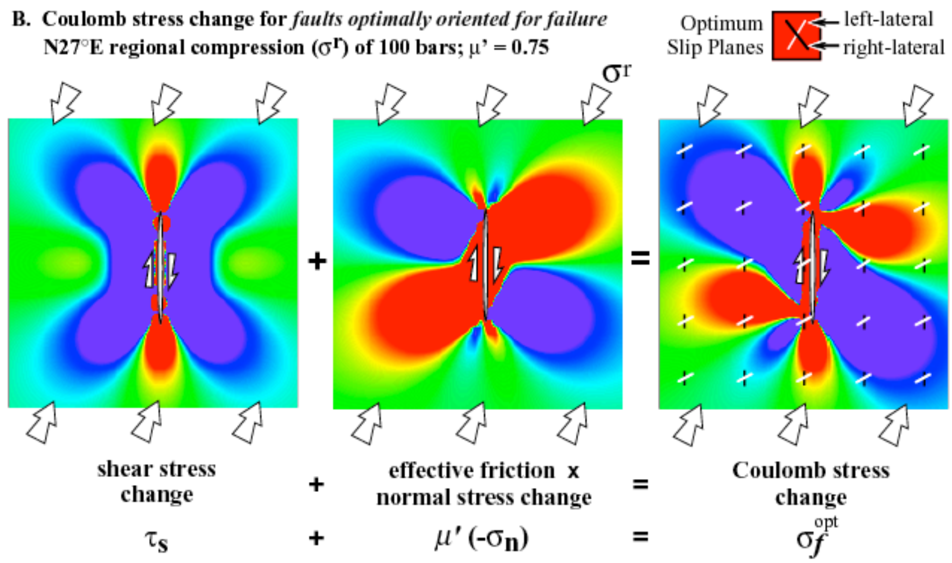
$$\Delta CFF = \Delta\tau + \mu(\Delta\sigma_n + \Delta P)$$



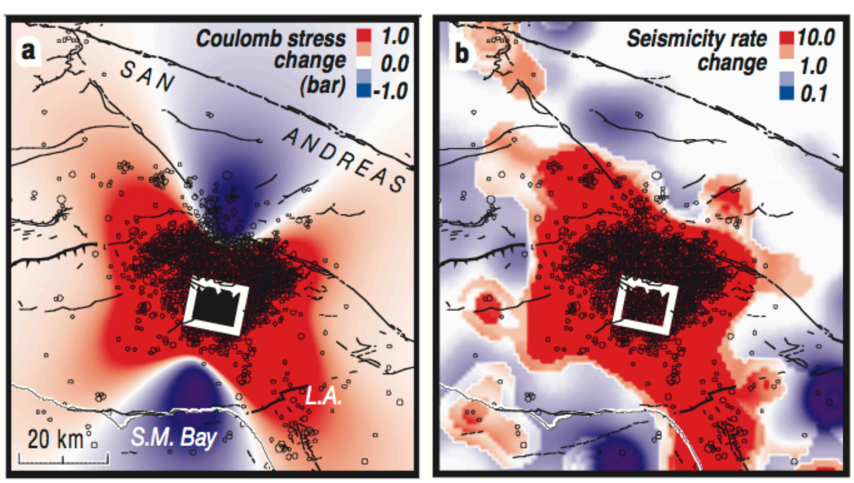


Stein, 1999

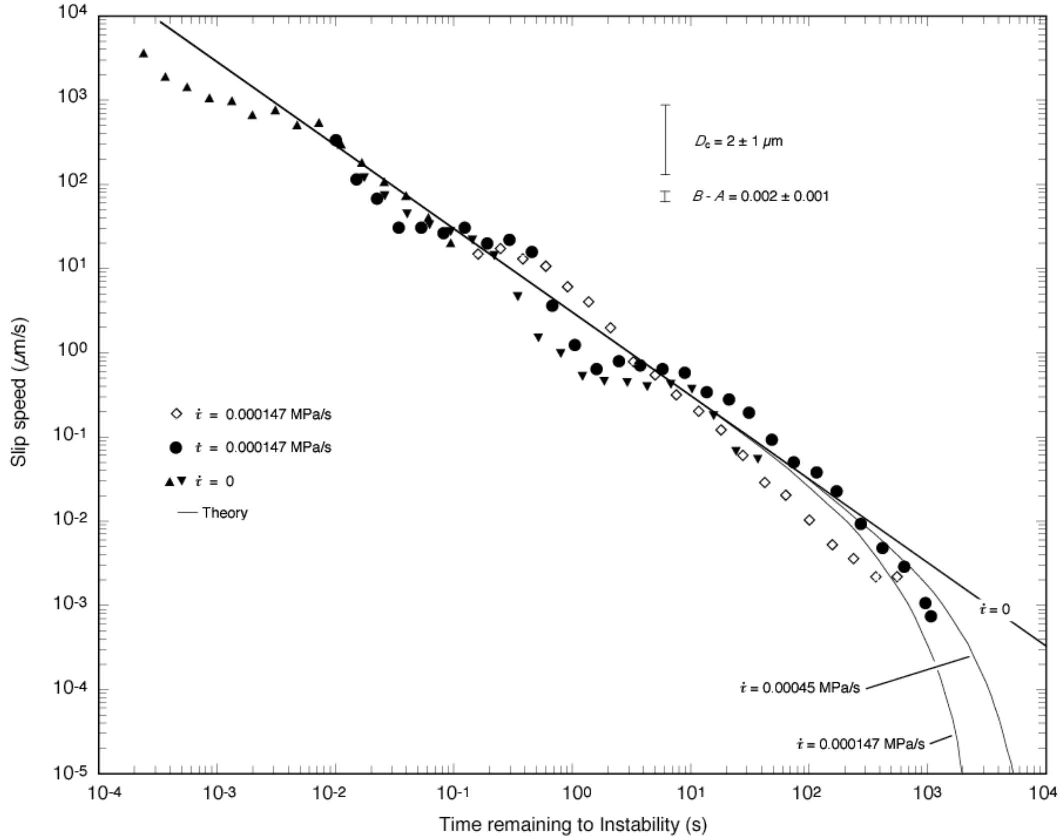




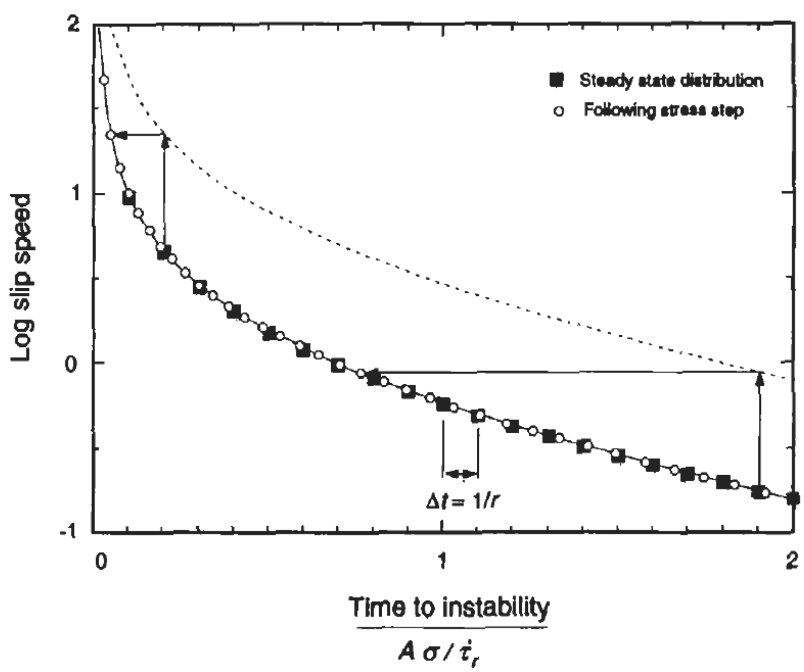
B. Coulomb stress change for *faults optimally oriented for failure*
N27°E regional compression (σ^r) of 100 bars; $\mu' = 0.75$
Optimum Slip Planes
left-lateral
right-lateral
σ^r
shear stress change
+
effective friction x normal stress change
=
Coulomb stress change
τ_s + $\mu'(-\sigma_n)$ = σ_f^{opt}



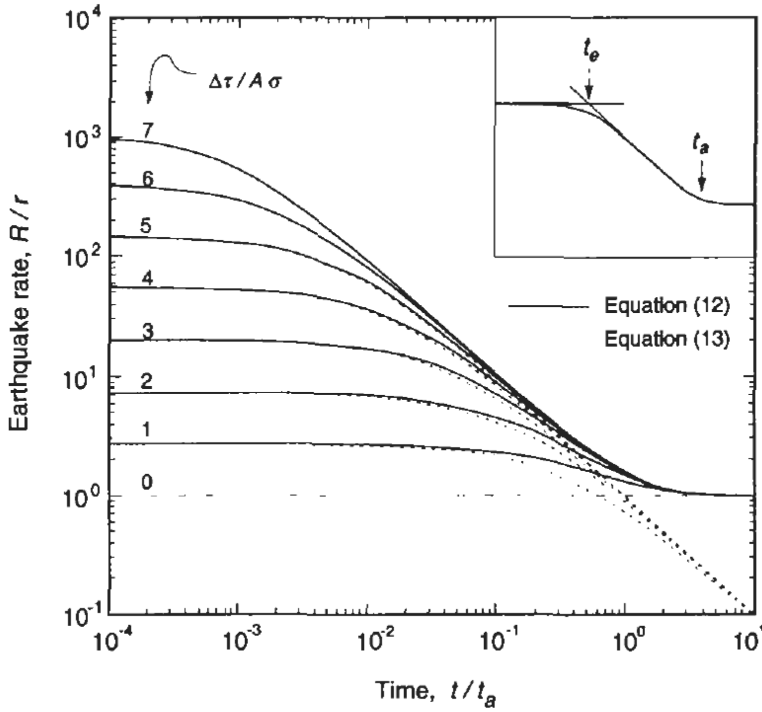
a
Coulomb stress change (bar)
1.0
0.0
-1.0
SAN ANDREAS
L.A.
S.M. Bay
20 km
b
Seismicity rate change
10.0
1.0
0.1



Slip speed (μm/s)
Time remaining to Instability (s)
$D_c = 2 \pm 1$ μm
$B - A = 0.002 \pm 0.001$
$\dot{\tau}$ = 0.000147 MPa/s
$\dot{\tau}$ = 0.000147 MPa/s
$\dot{\tau}$ = 0
Theory
$\dot{\tau}$ = 0
$\dot{\tau}$ = 0.00045 MPa/s
$\dot{\tau}$ = 0.000147 MPa/s



Log slip speed
Steady state distribution
Following stress step
Δt = 1/r
Time to instability / $A\sigma/\dot{\tau}_r$



$$R(t) = \frac{r}{\left[\exp\left(\frac{-\Delta\sigma_f}{A\sigma_n}\right) - 1\right]\exp\left(\frac{-t}{t_a}\right) + 1}$$

What is t_A?

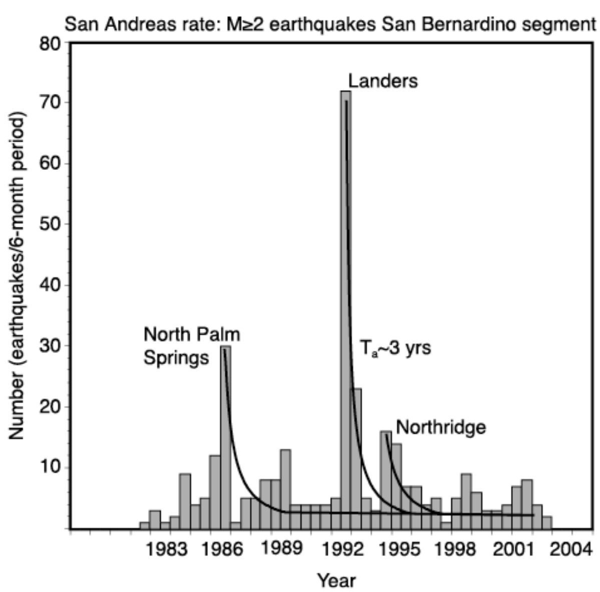


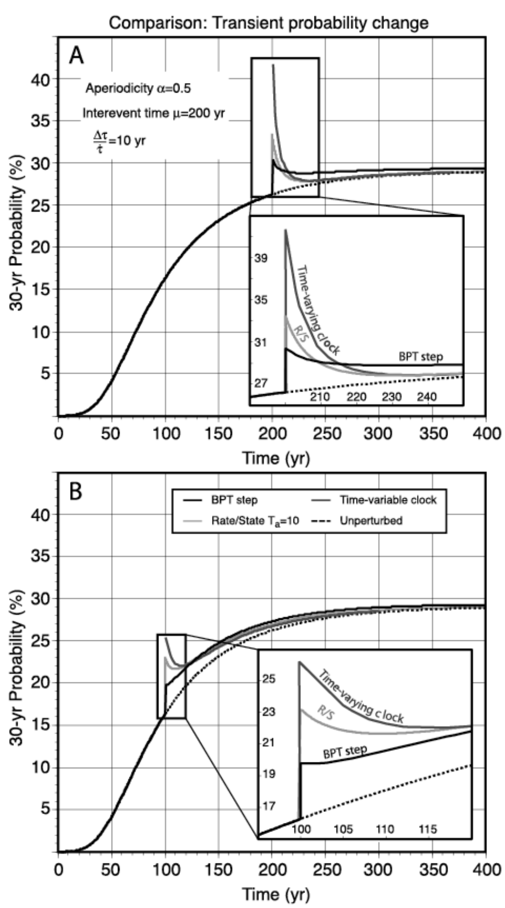
Figure 19. Seismicity rate changes within ±1 km of the San Andreas fault (trace shown in Figure 18). The aftershock durations from three earthquakes are shown. In all cases the rate returns to background within ~3 years.

Parsons, 2005

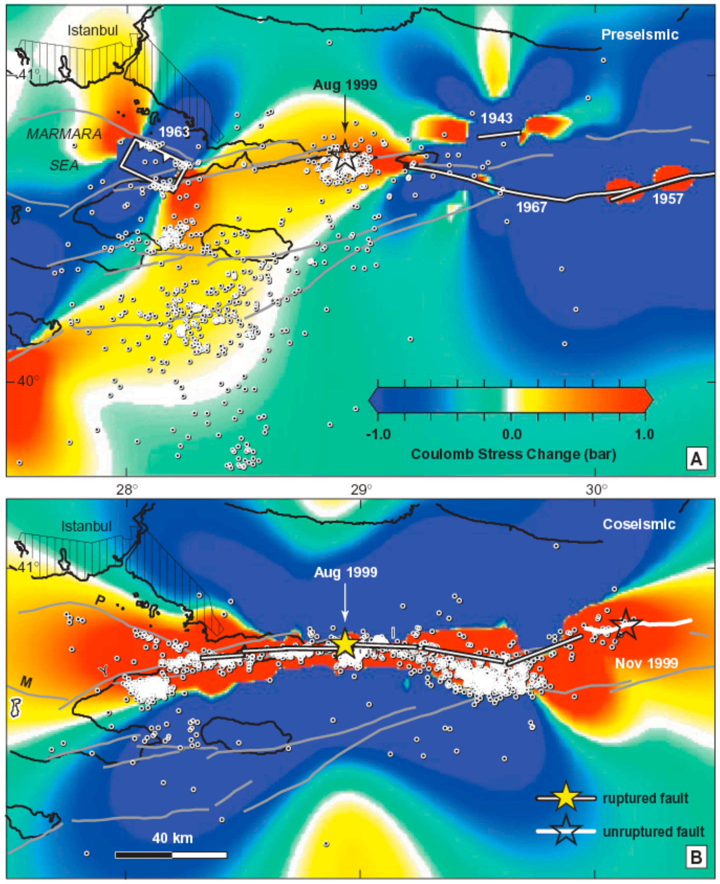
The transient change in expected earthquake rate $R(t)$ after a stress change, $R(t) = r/[\exp(-\Delta\tau/a\sigma) - 1]\exp(-t/t_a) + 1$, can be related to the probability of an earthquake of a given size over the time interval Δt through a nonstationary Poisson process as

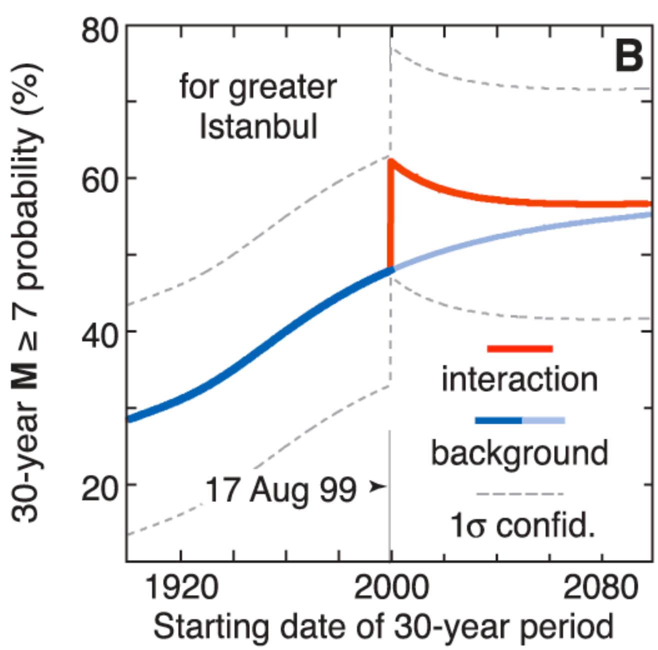
$$P(t,\Delta t) = 1 - \exp\left[- \int_{t}^{t+\Delta t} R(t)dt \right]$$

The transient probability change is superimposed on the permanent change, which results from an advance or delay in the expected time until failure caused by the stress change.



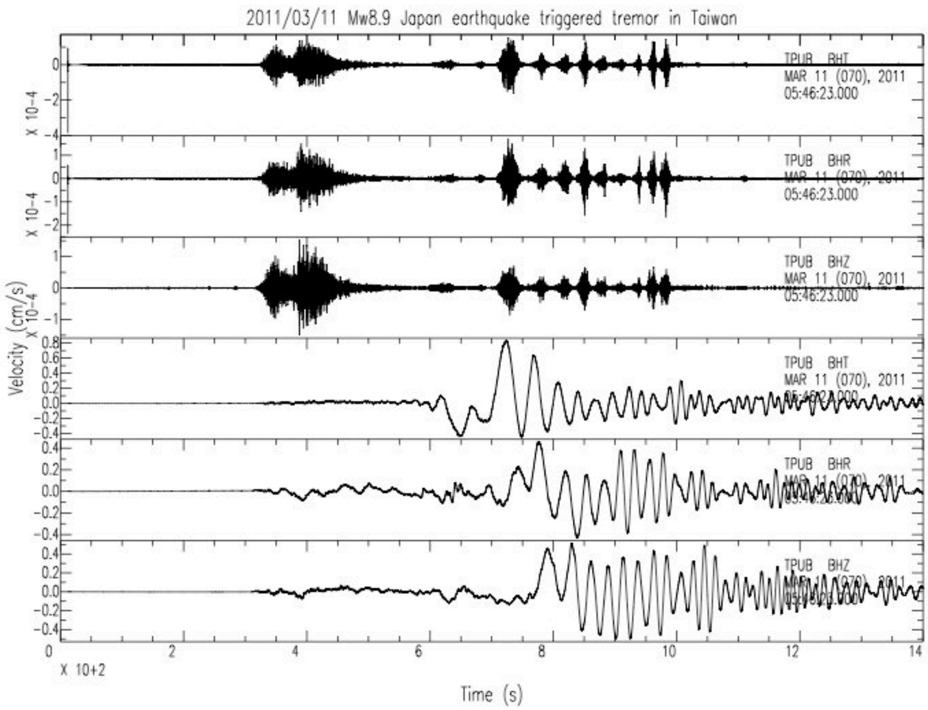
Parsons, 2005





Heightened Odds of Large Earthquakes Near Istanbul: An Interaction-Based Probability Calculation Tom Parsons, *et al.*
Science **288**, 661 (2000); DOI: 10.1126/science.288.5466.661

Long-period surface waves triggered tremor in southern Taiwan (Z. Peng) and probably elsewhere



5 Hz high-pass-filtered on the top, and broadband velocity trace on the bottom