CONSTRAINTS ON FAULT PROPERTIES OF TOHOKU-OKI RUPTURE ZONE

From Integration of Observations and Dynamic Rupture Models

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More Interactions Needed!

Dynamic Rupture Modeling

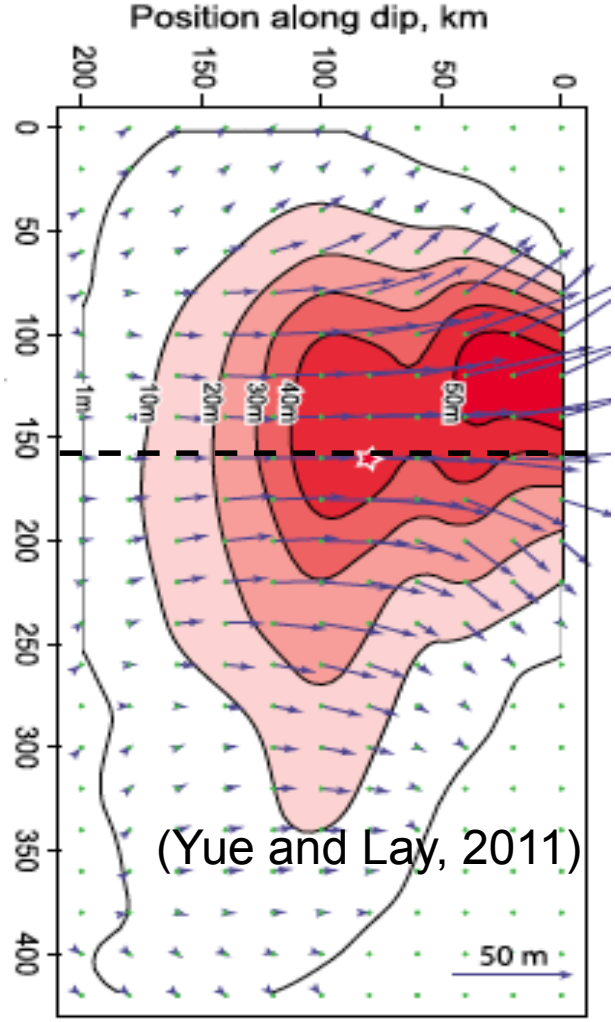
(http://www.wpclipart.com)

Observational Seismology

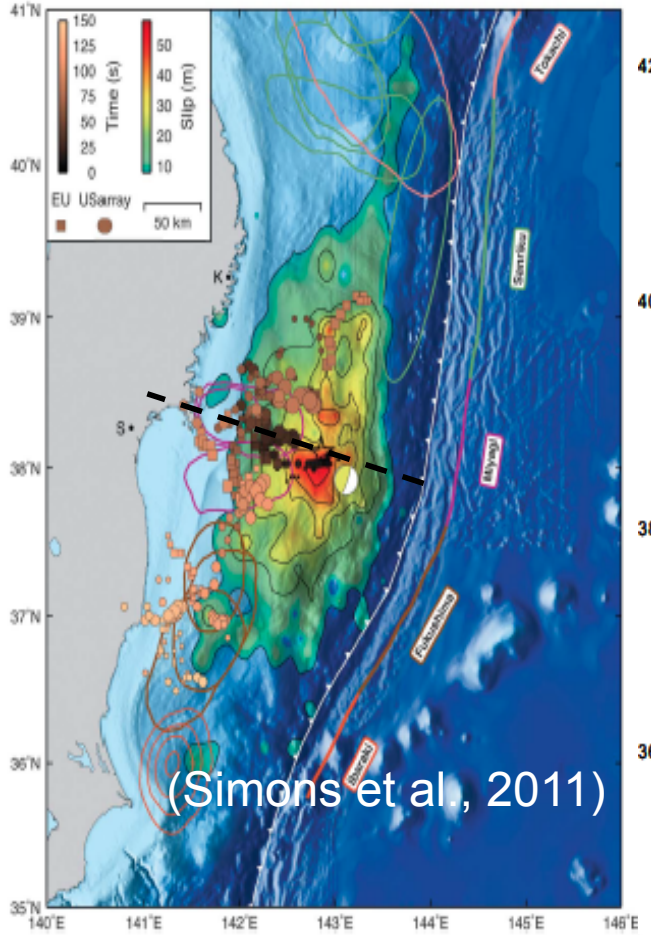
(http://www.dereksdiscourse.com/)

Ishinomaki before and after Tohoku-Oki EQ

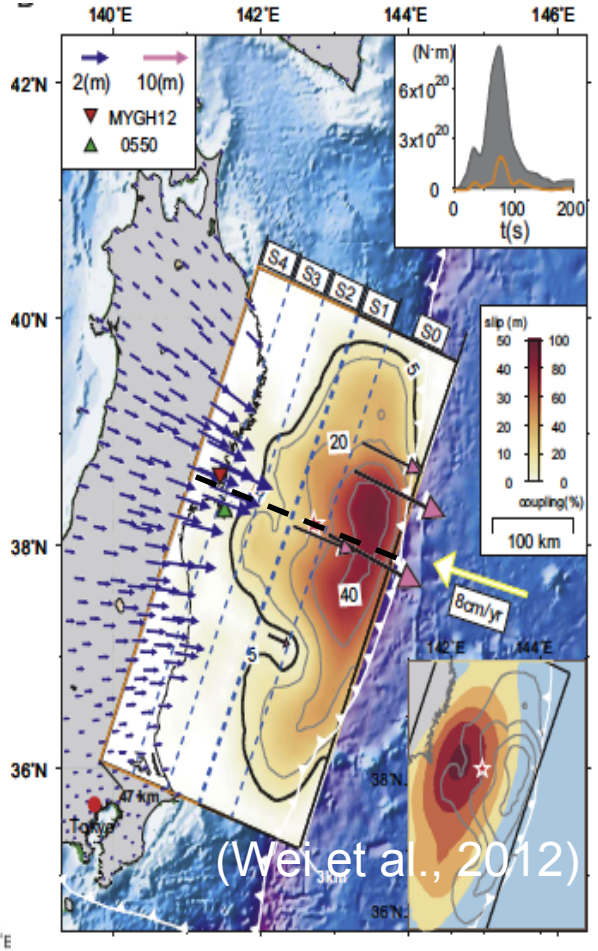
2011 Tohoku-Oki Earthquake: Slip reaches the shallower region



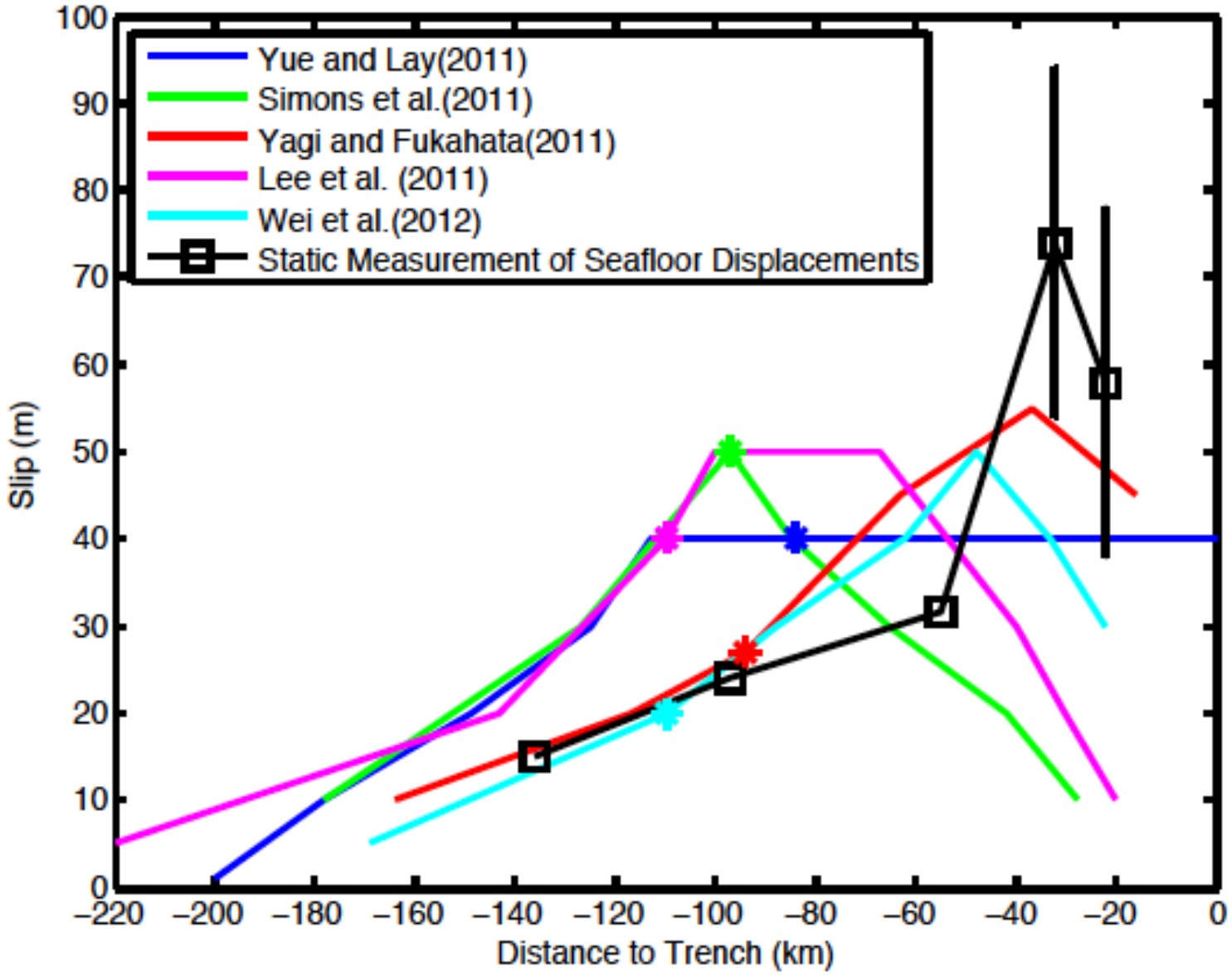
(Yue and Lay, 2011)

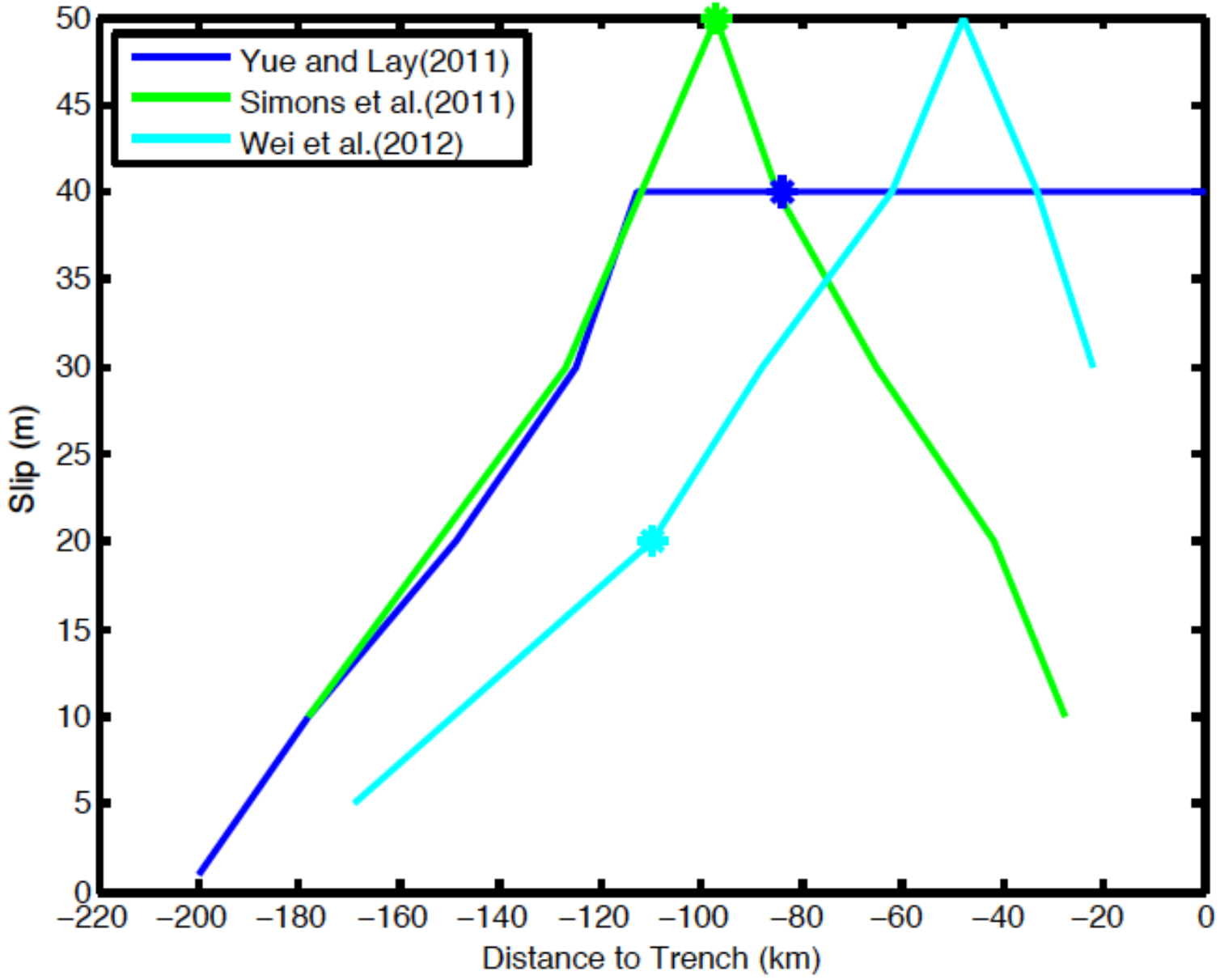


(Simons et al., 2011)

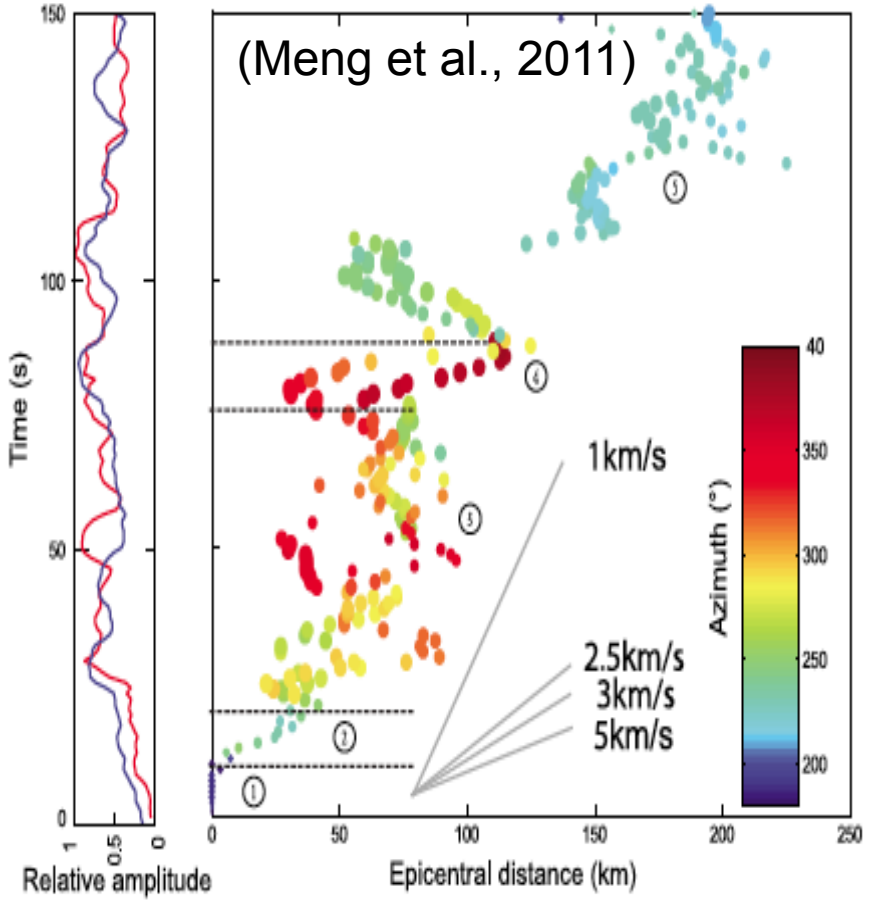


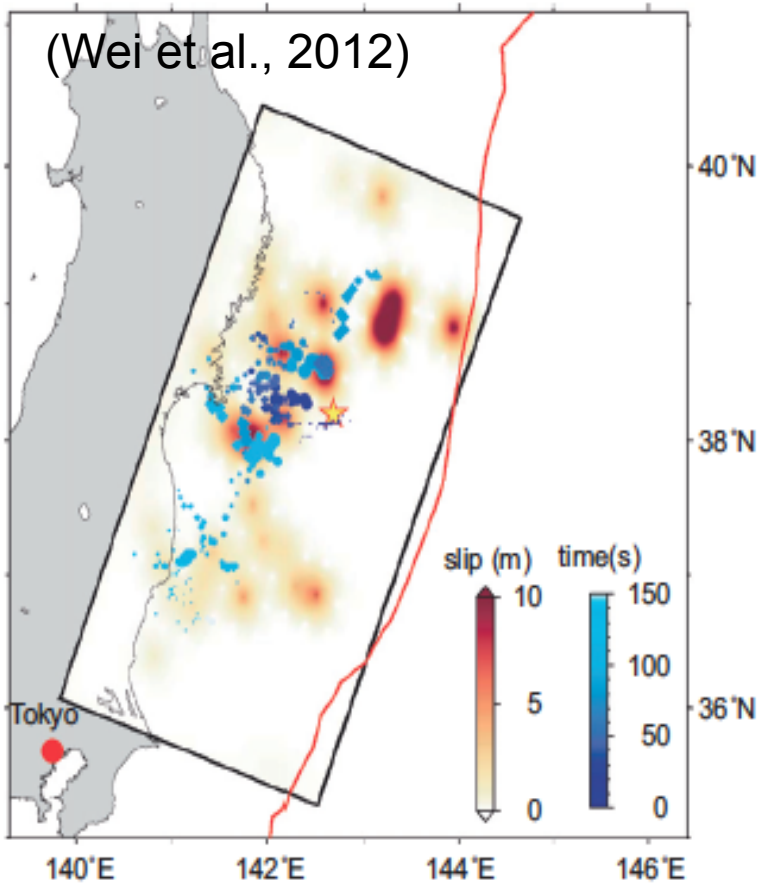
(Wei et al., 2012)


Yue and Lay(2011)
Simons et al.(2011)
Yagi and Fukahata(2011)
Lee et al. (2011)
Wei et al.(2012)
Static Measurement of Seafloor Displacements
Slip (m)
Distance to Trench (km)
100
90
80
70
60
50
40
30
20
10
0
−220
−200
−180
−160
−140
−120
−100
−80
−60
−40
−20
0


Yue and Lay(2011)
Simons et al.(2011)
Wei et al.(2012)
Slip (m)
Distance to Trench (km)
50
45
40
35
30
25
20
15
10
5
0
−220
−200
−180
−160
−140
−120
−100
−80
−60
−40
−20
0

2011 Tohoku-Oki Earthquake: Slow down-dip rupture with HF bursts





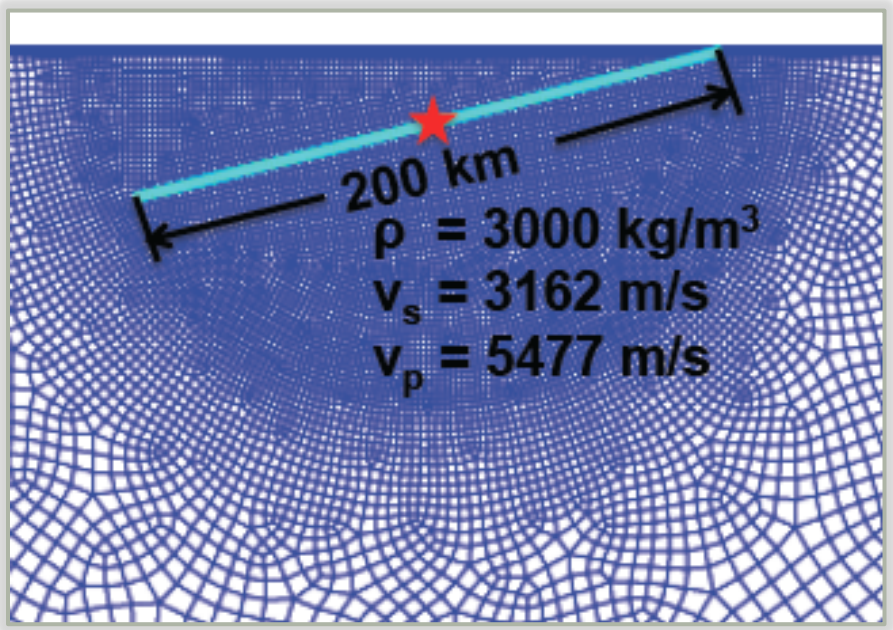
2011 Tohoku-Oki Earthquake

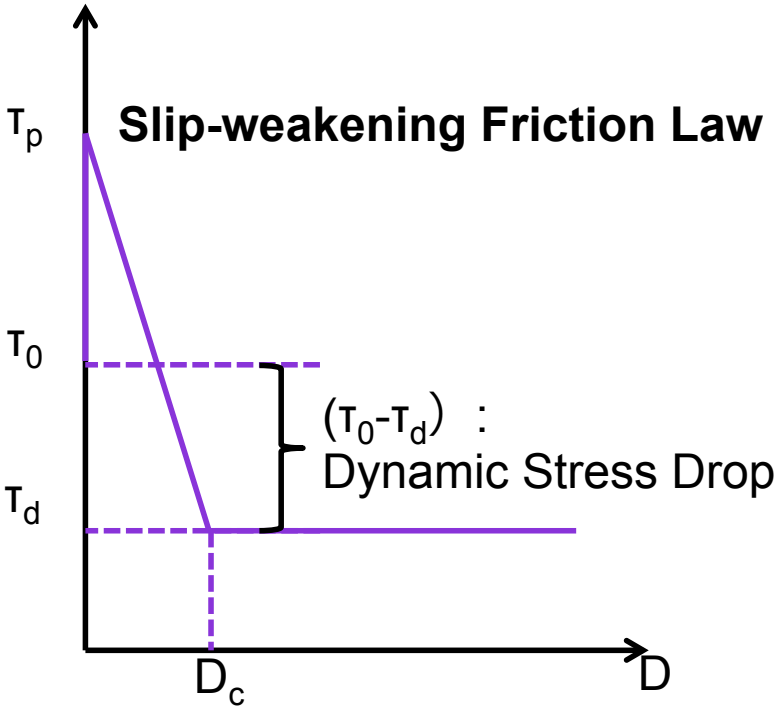
- Large slip reaches the shallower region, and possibly extends to the trench.
- The rupture velocity is slow in the down-dip region (~1 km/s). The up-dip rupture probably reaches the trench at ~ 40-80 s.
- The frequency contrast between up-dip and down-dip region is quite large. The power ratio is estimated to be ~ 10 (Huang et al., 2012).

Dynamic Rupture Model

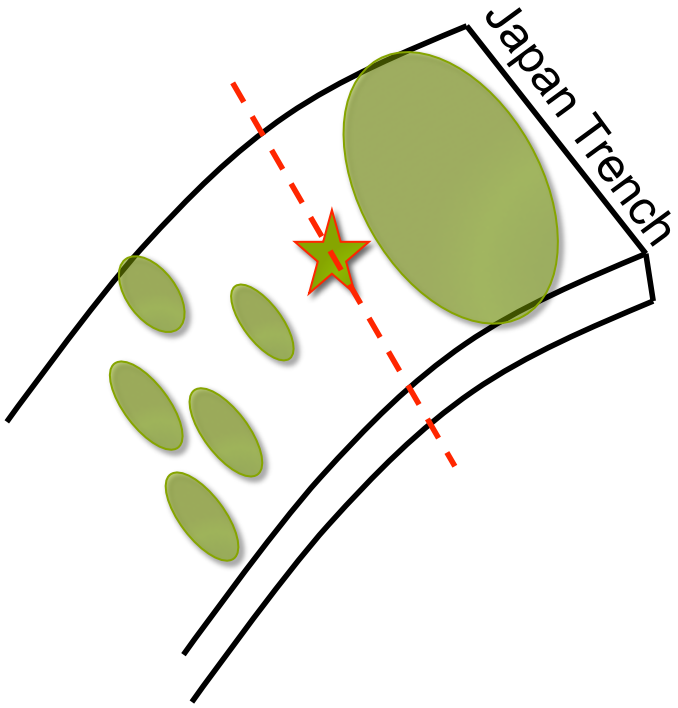
- Our aim is to understand the fault properties and explain the physics behind Tohoku-Oki Earthquake.
- So we start by reproducing the different types of slip profiles, slow down-dip rupture and frequency contrasts.
- We will compare the different fault properties that are implied by the different simulations, especially in terms of energy partitioning.

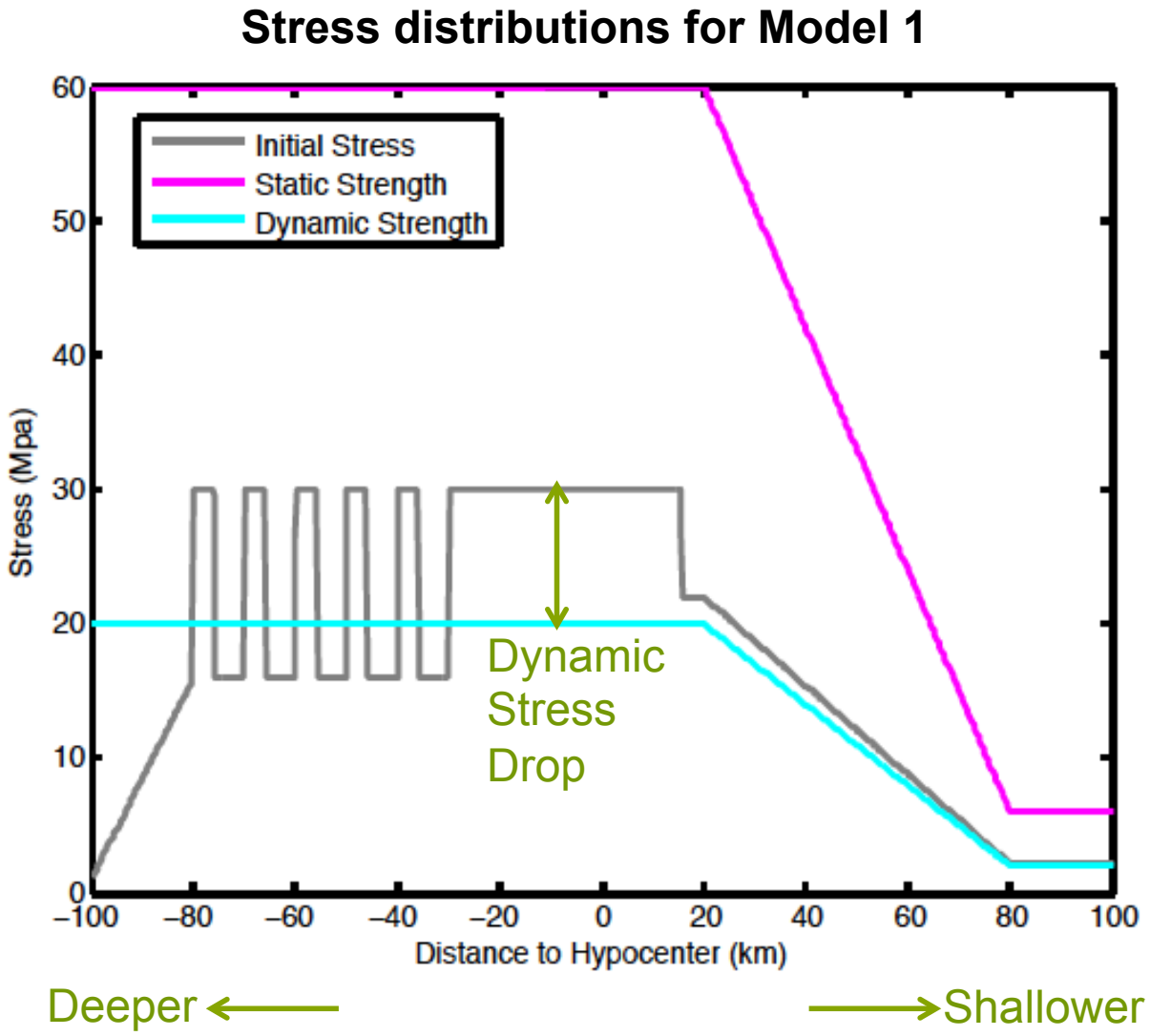
A model that can potentially explain the observations with fewest assumptions.





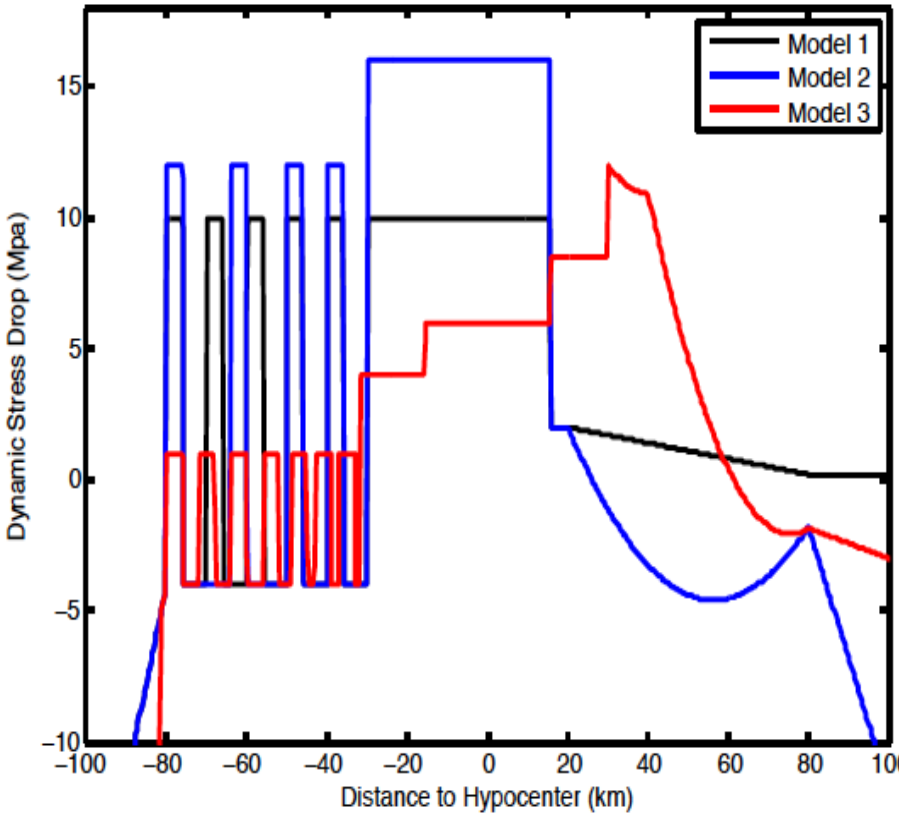
Asperity Model



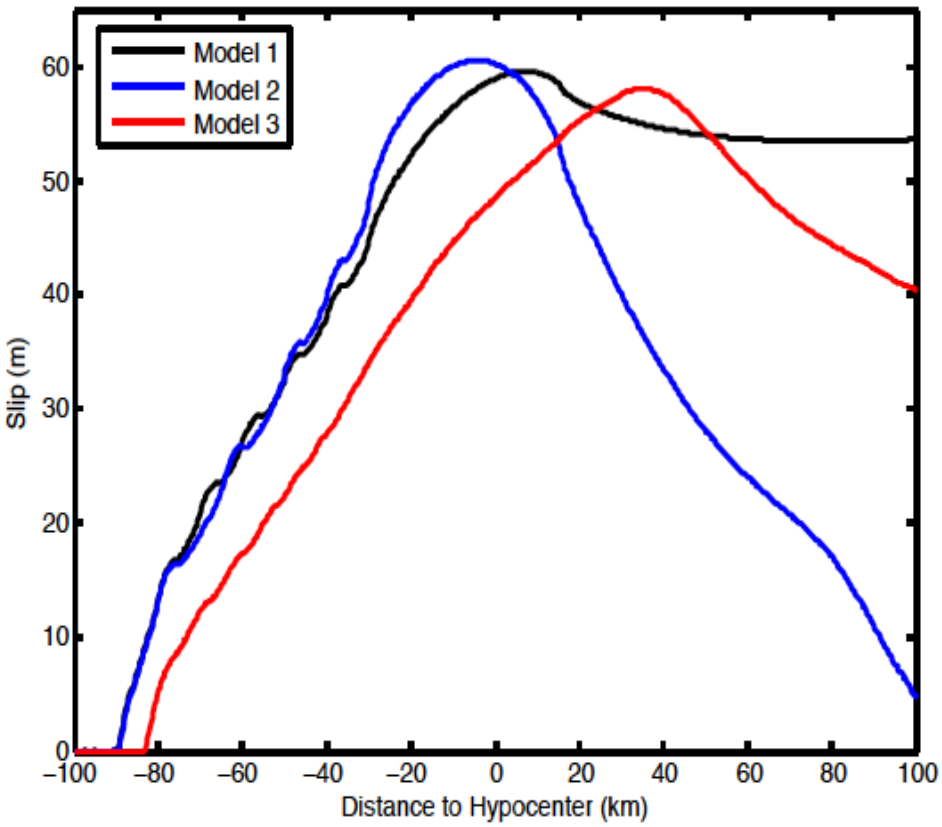


Results: Slip

Input

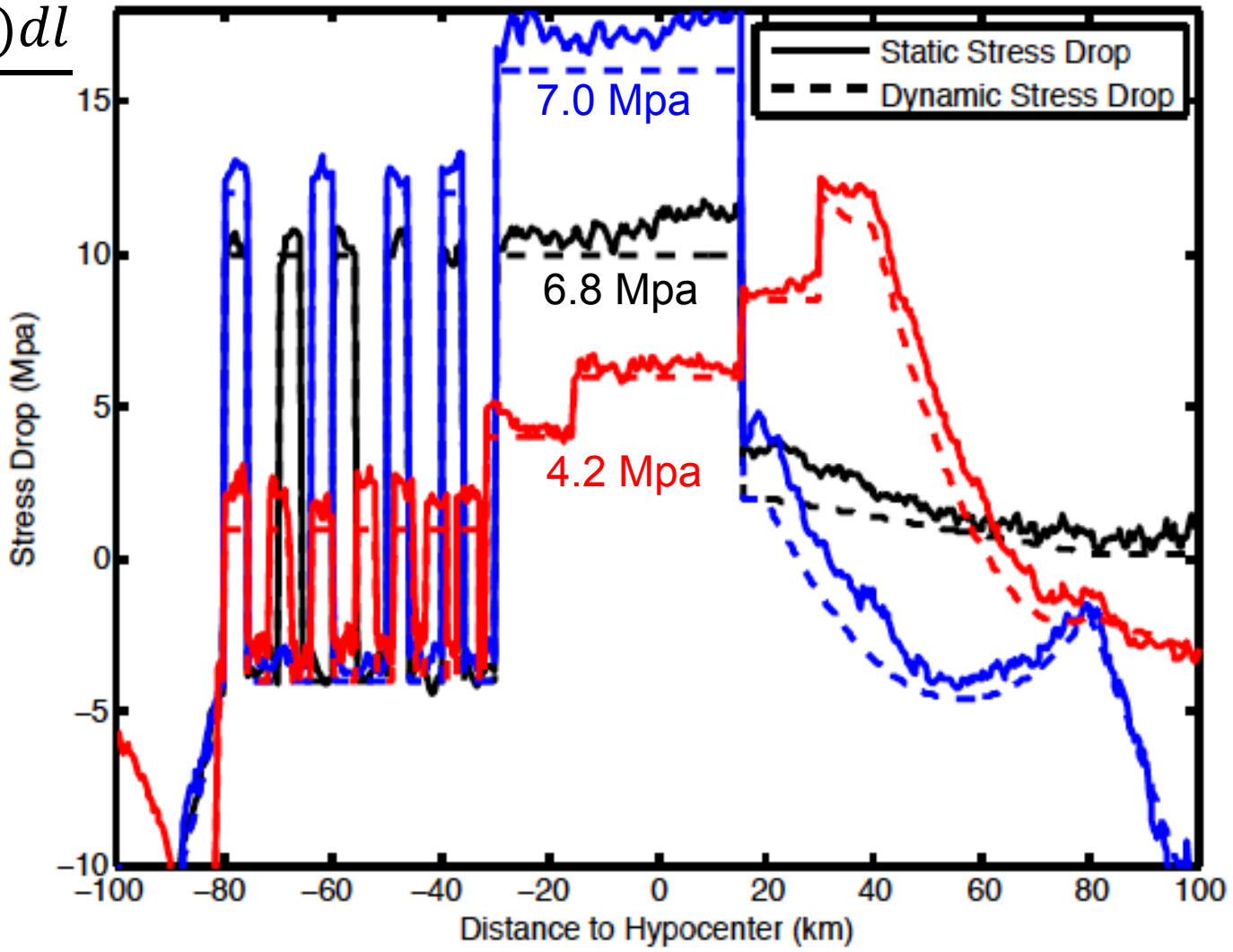


Output

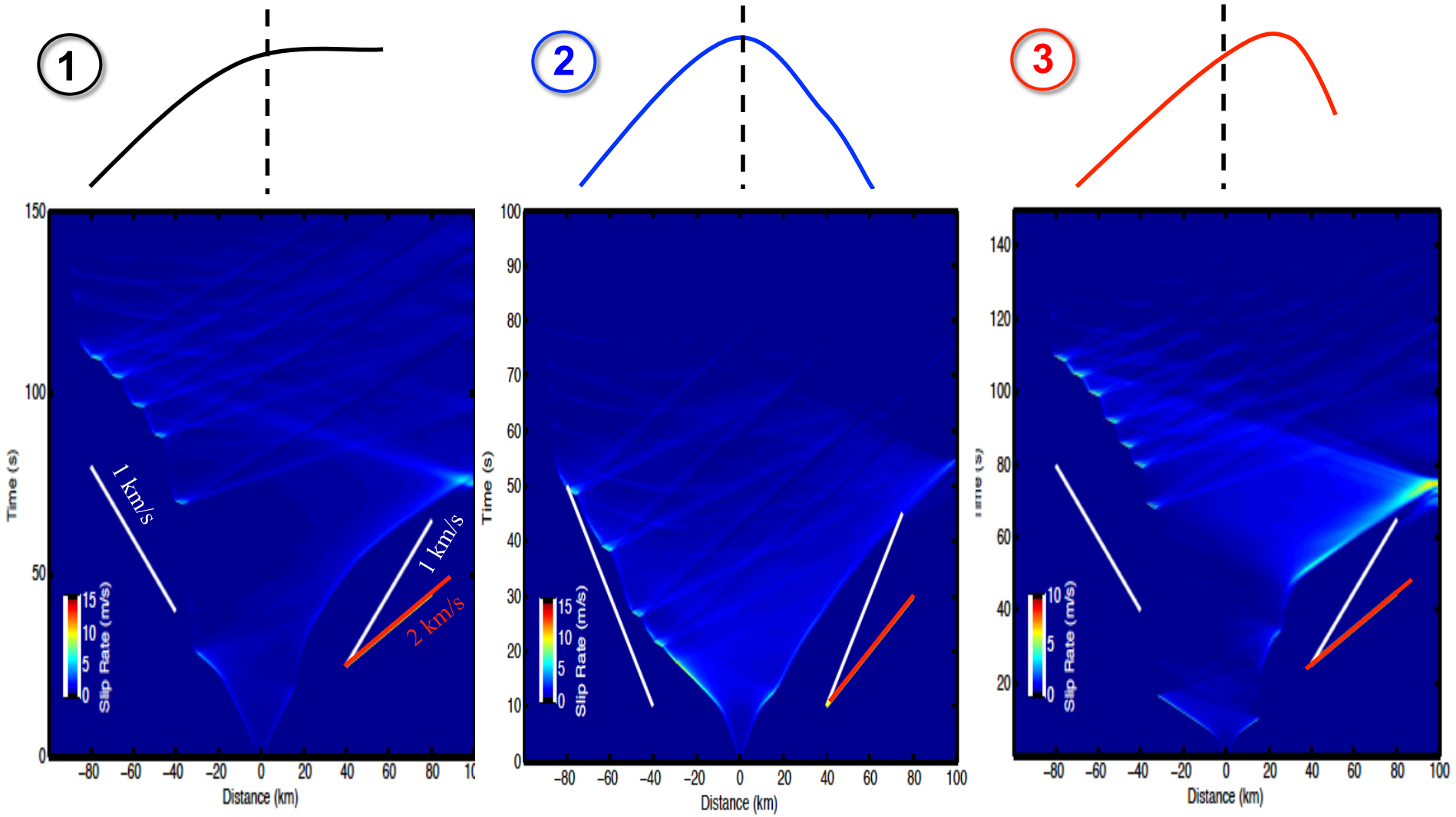


Results: Static Stress Drop and Overshoot

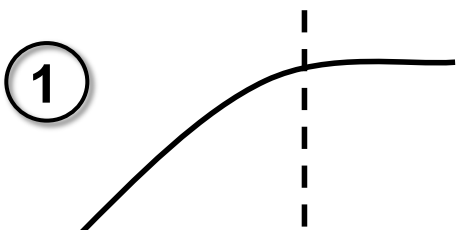
$$\frac{\int(\Delta\sigma \cdot D)dl}{\int D dl}$$

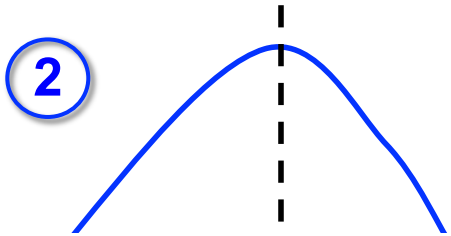


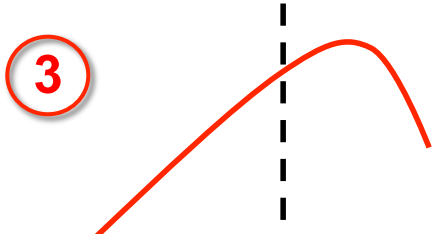
Results: Rupture Velocity

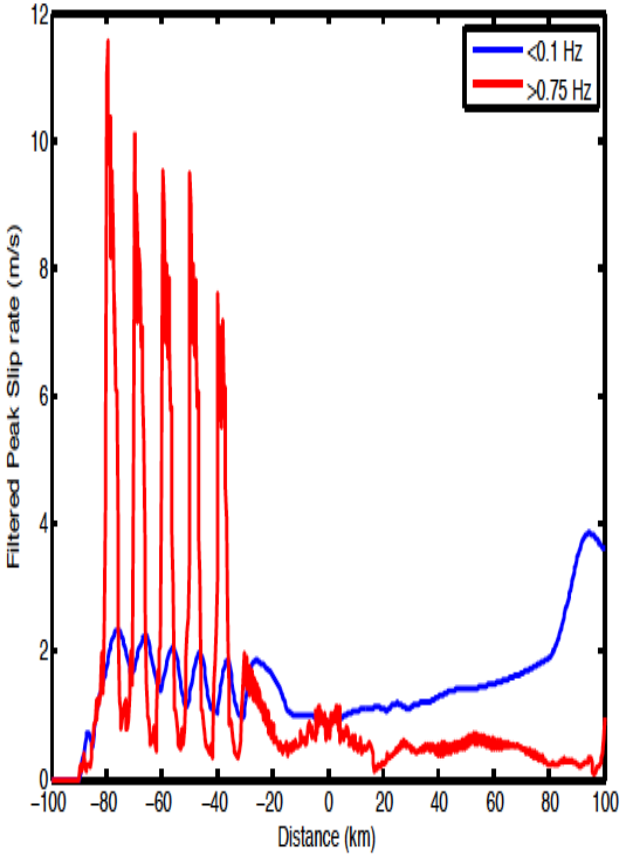


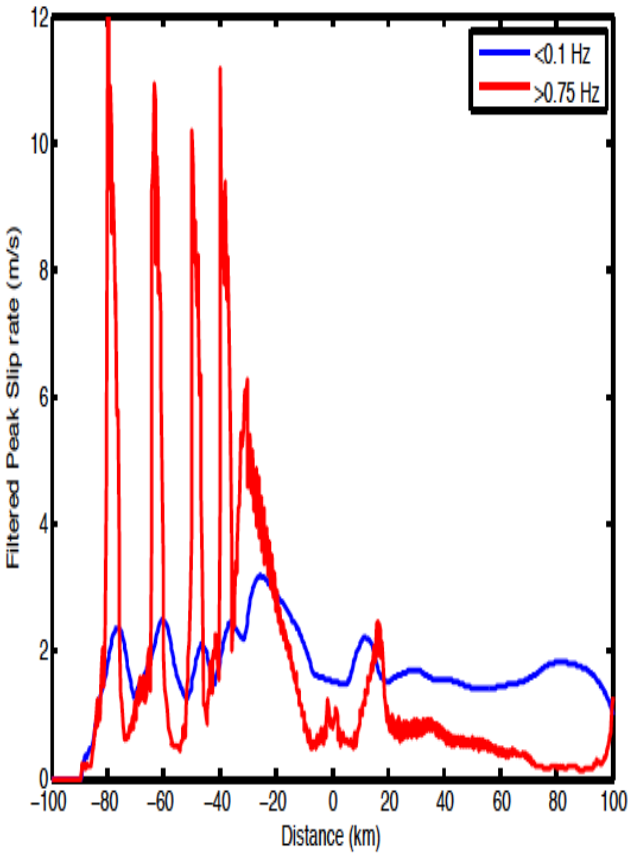
Result: Frequency Contrasts

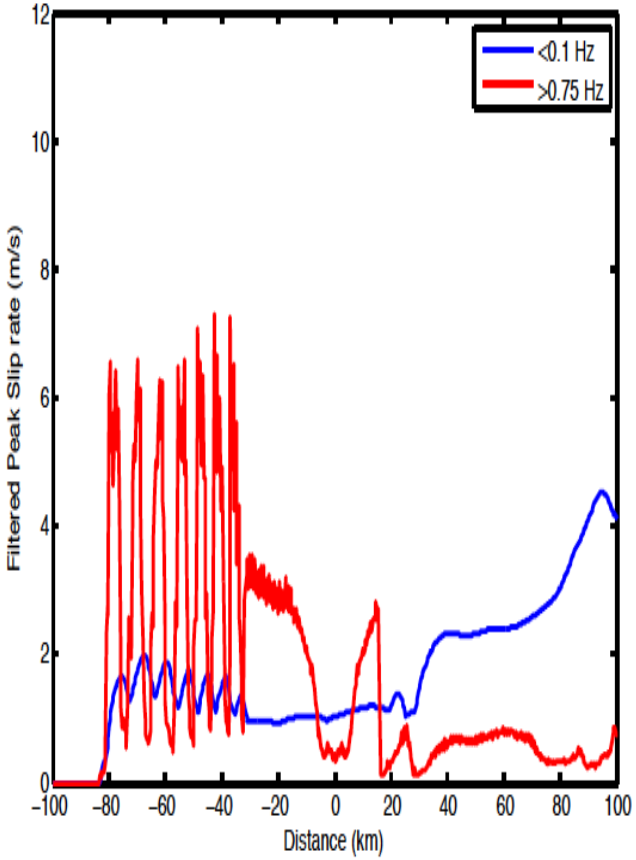




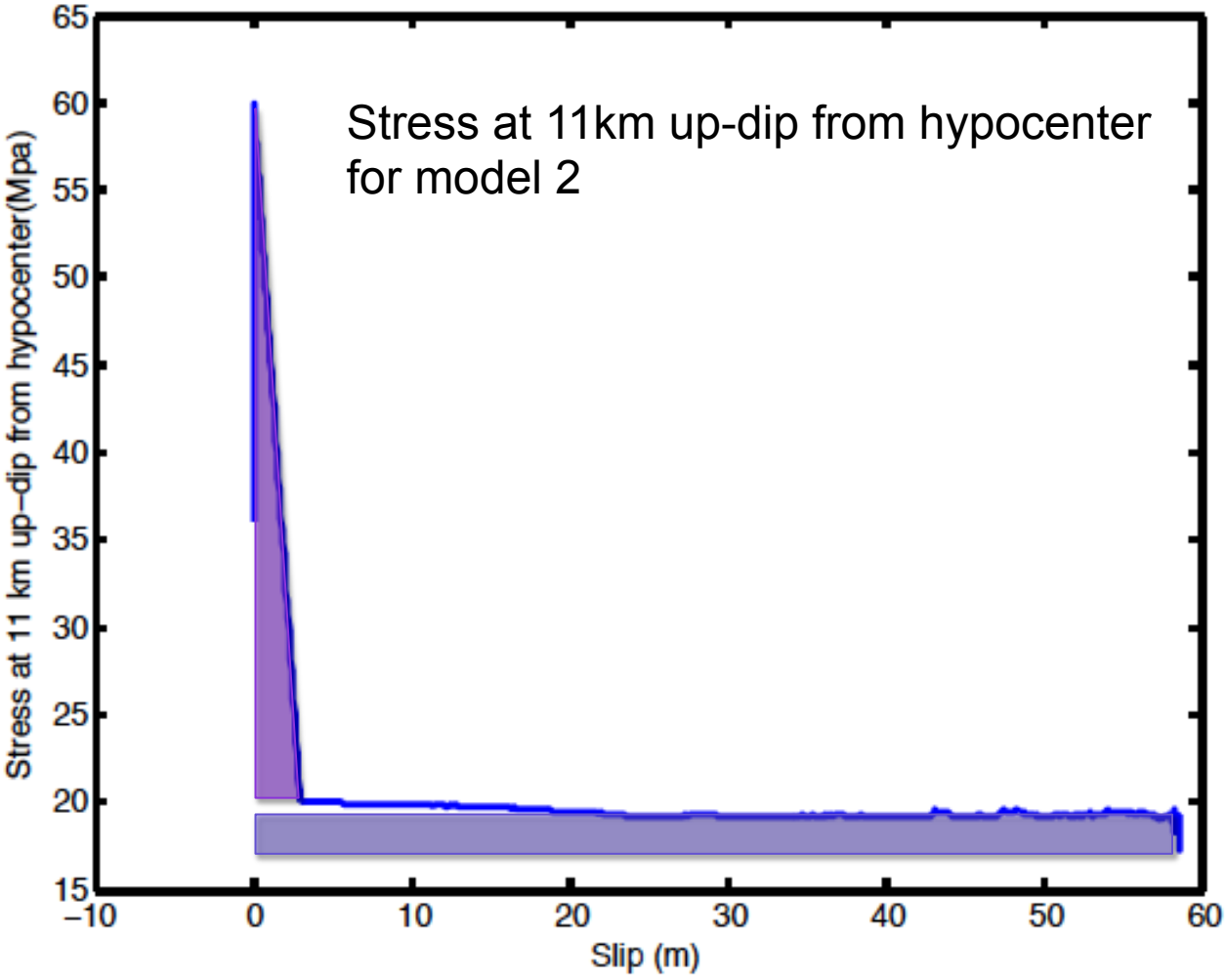




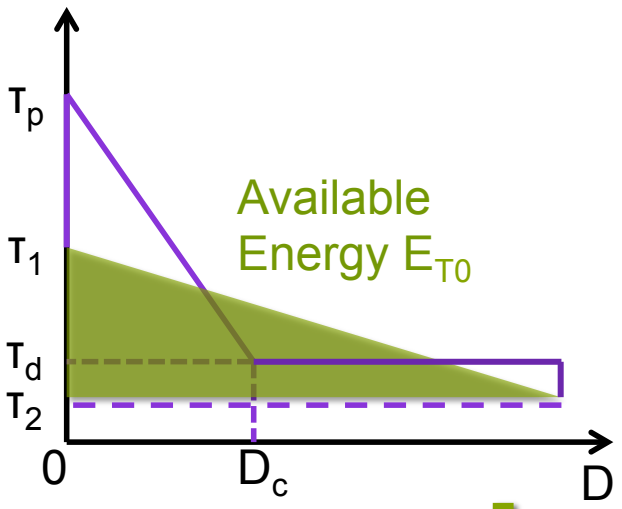


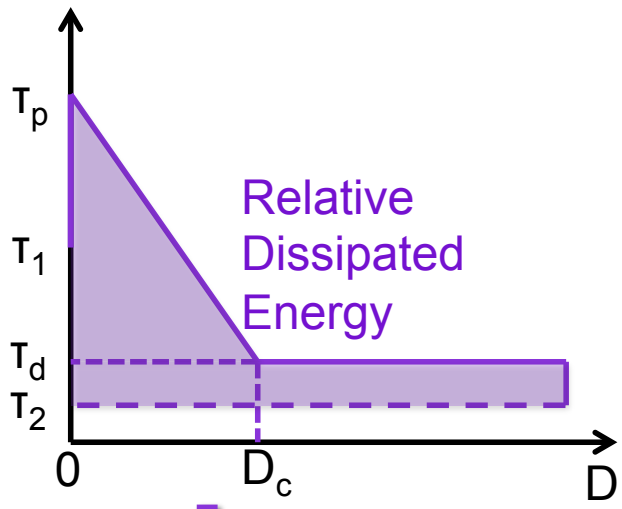


Result: Energy Partitioning



Results: Energy Partitioning





Radiated Energy:

$$E_R = \frac{1}{2}(\tau_1 - \tau_2)DA - \left[A\int_0^D \tau dD - \tau_2 DA\right]$$

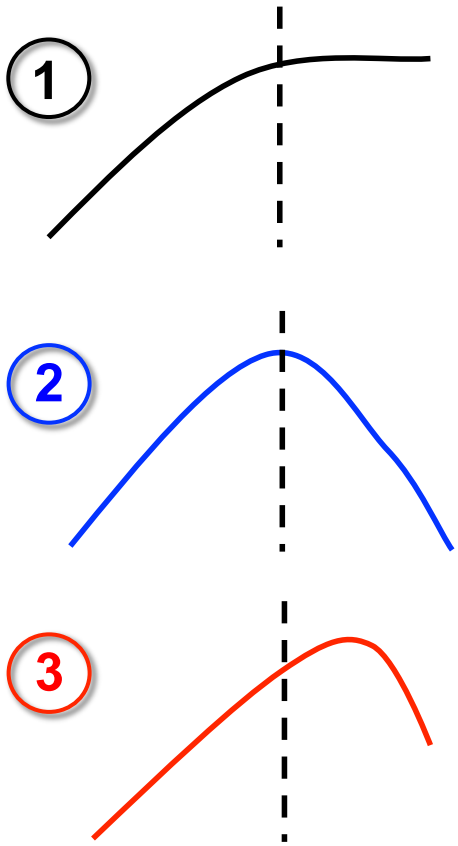
Radiation Efficiency:

$$\eta_R = E_R / E_{T0}$$

(e.g., Kanamori and Rivera, 2006)

Results: Radiation Efficiency

Models:



$\eta_R = 0.37$

$\eta_R = 0.43$

$\eta_R = 0.53$

Observation:

$$\eta_R = (2\mu/\Delta\tau)(E_R/M_0)$$
$$\approx (2 \times 30Gpa/6Mpa) \times (10^{-5})$$
$$= 0.1$$

Conclusions

- Observations are reproduced with a simple model.
- Once the hypocenter region is broken, the rupture can easily propagate to the shallower region even with negative stress drop, because of the wedge structure.
- The down-dip region is likely to have small asperities, which slow down the rupture and make high frequency bursts.
- The radiation efficiency from 2D model is higher than the observed value. Another dissipation energy mechanism is needed.