WHAT CAN A SIMPLE SLIP-WEAKENING MODEL OF THE TOHOKU EQ TELL US?

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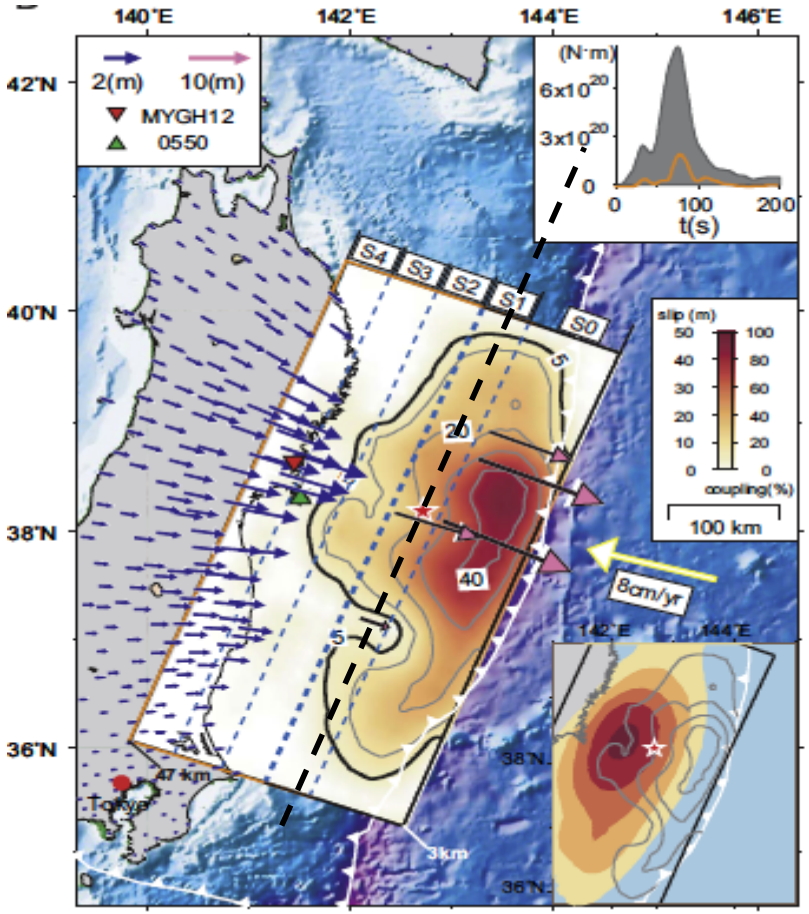
Outline

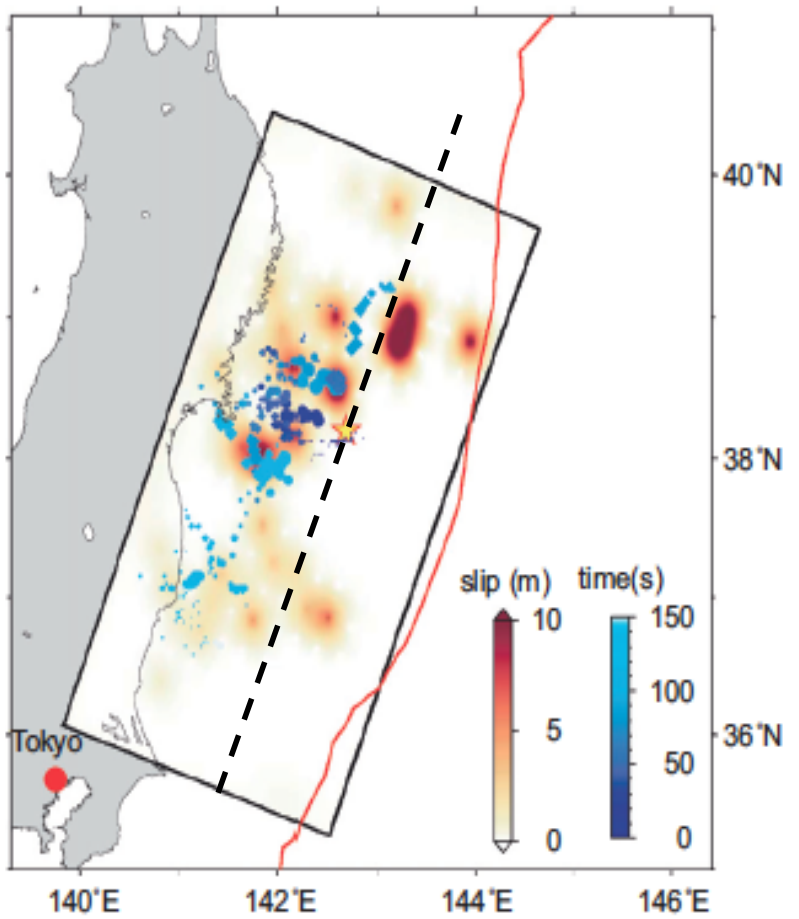
1. Summarize the robust observations of the Tohoku Earthquake.

2. Perform dynamic modeling of the Tohoku Eq. Show how observations constrain model parameters.

3. What can/cannot the slip-weakening models tell us?

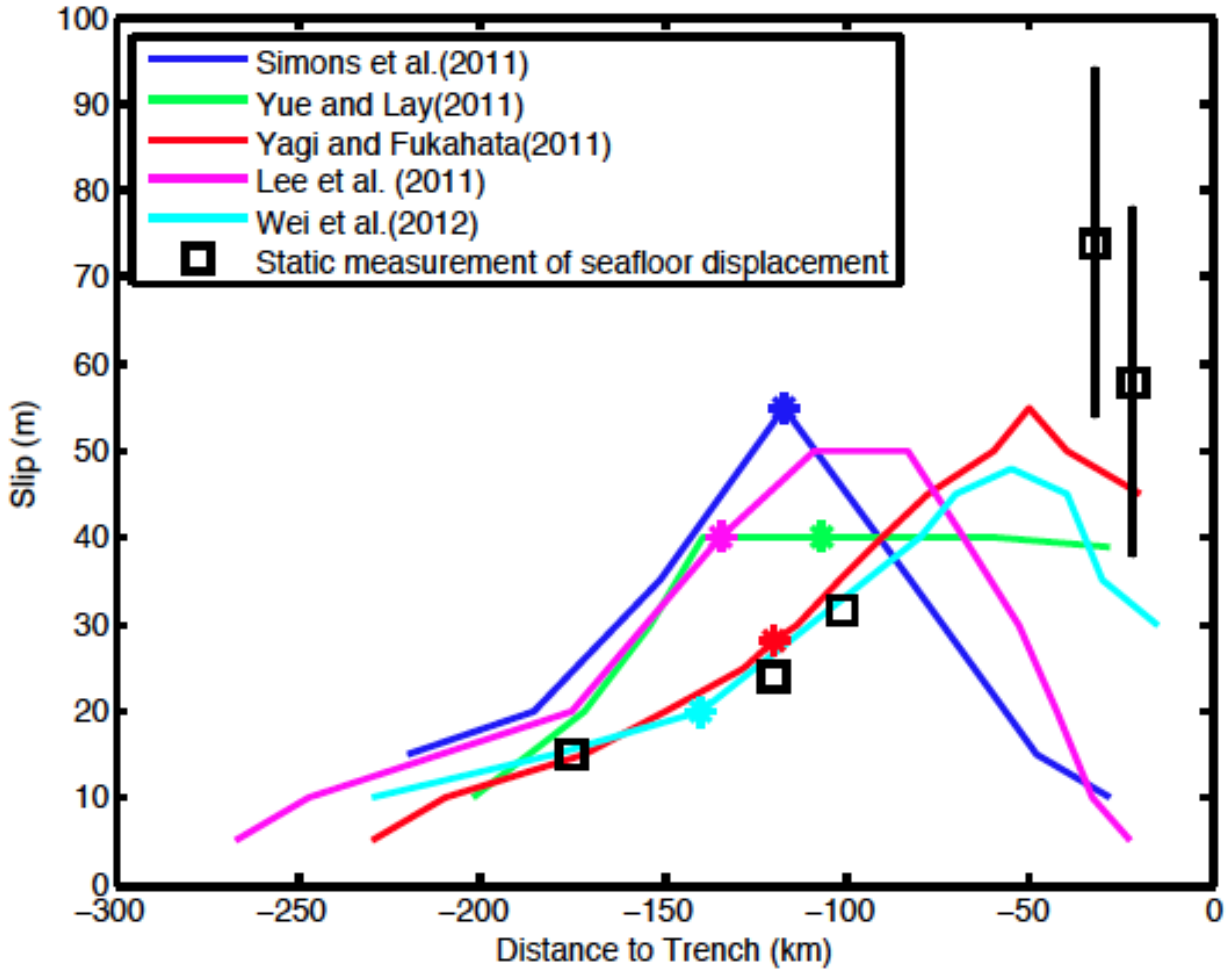
- Observations suggest strikingly different behaviors of shallower and deeper regions of the Tohoku Earthquake.



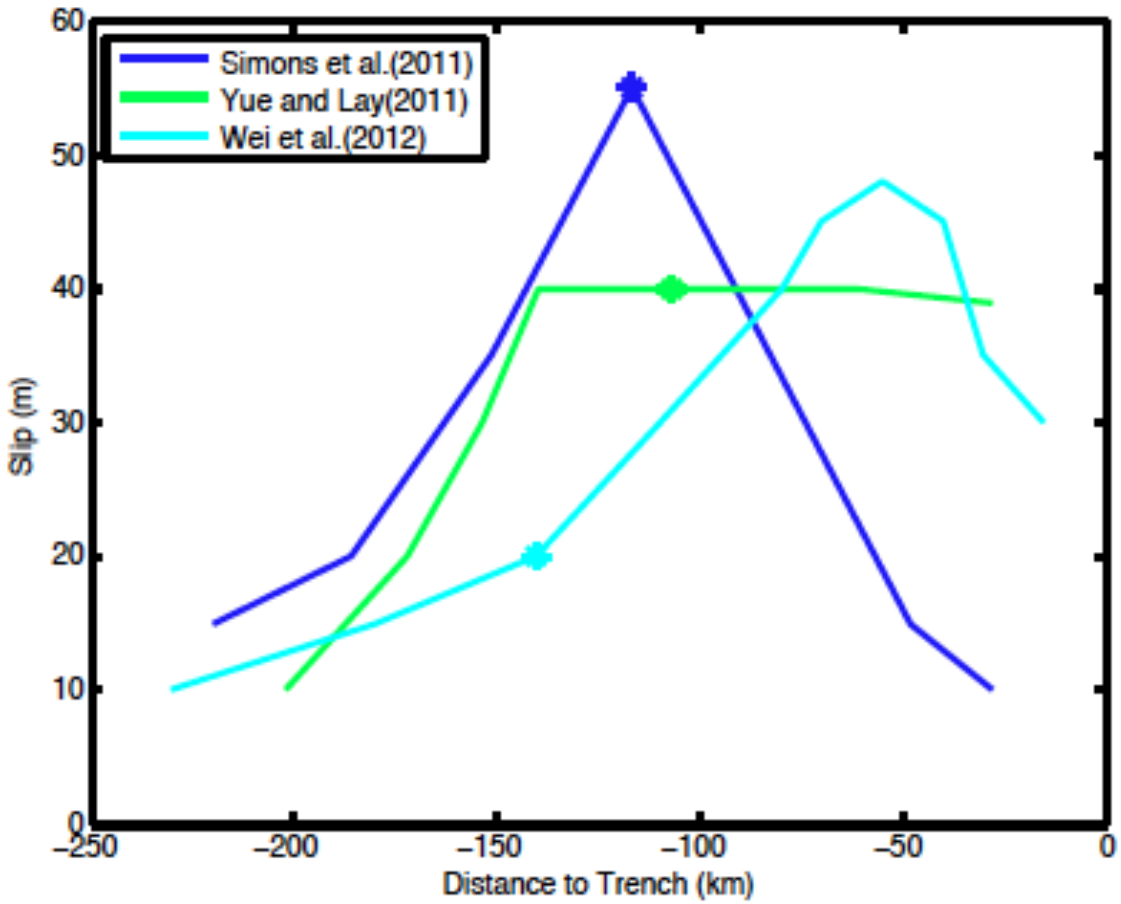


(Wei et al., EPSL, 2012)

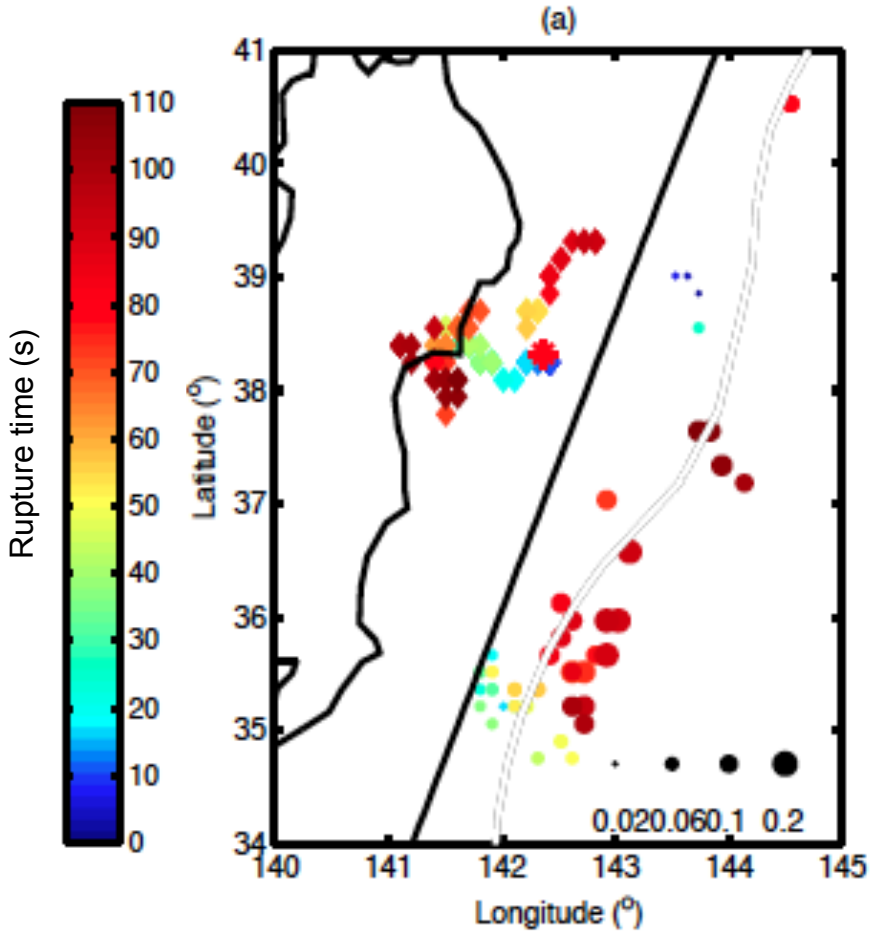
- Slip in the shallower region varies in different models.



- But they fall into 3 groups. The absolute level is different.



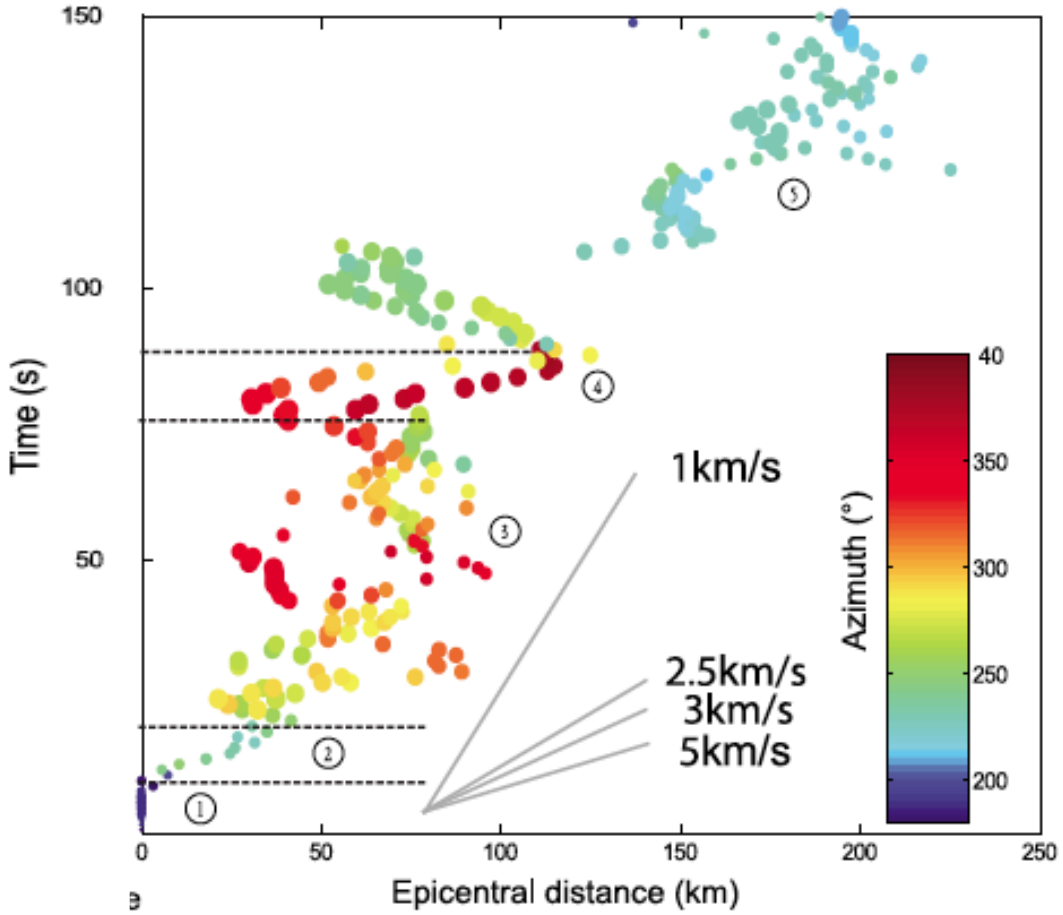
- Can we get an upper bound of the HF power of shallower region?



The HF power in the deeper region
~ 10 times of that in the shallower region.

(Huang et al., EPS, 2012)

- If HF radiation mostly comes from the down-dip rupture front, it can give a fairly good estimation of rupture speed.

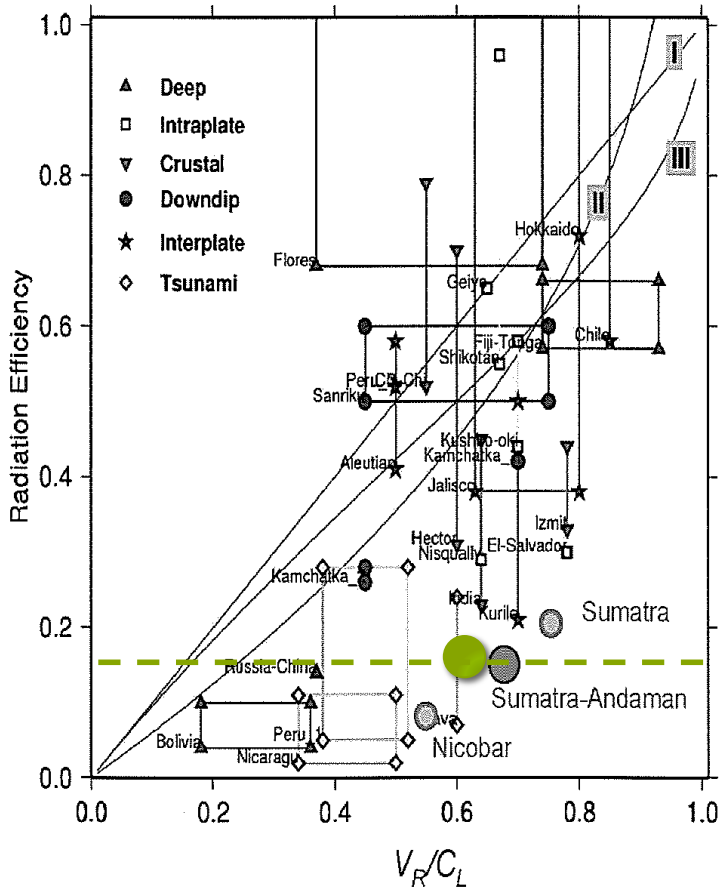


(Meng et al., GRL, 2012)

- The total radiated energy from the earthquake constitutes only a small part of the available energy.

$$\eta_R = (2\mu/\Delta\tau)(E_R/M_0) \approx 0.15$$

Stress drop $\Delta\tau \sim 4$ Mpa
Scaled energy $E_R/M_0 \sim 10^{-5}$
Shear modulus $\mu \sim 30$ Gpa,



(Kanamori, AGU, 2006)

Observations of Tohoku Earthquake

Shallower region:

- Large slip;
- LP radiation.

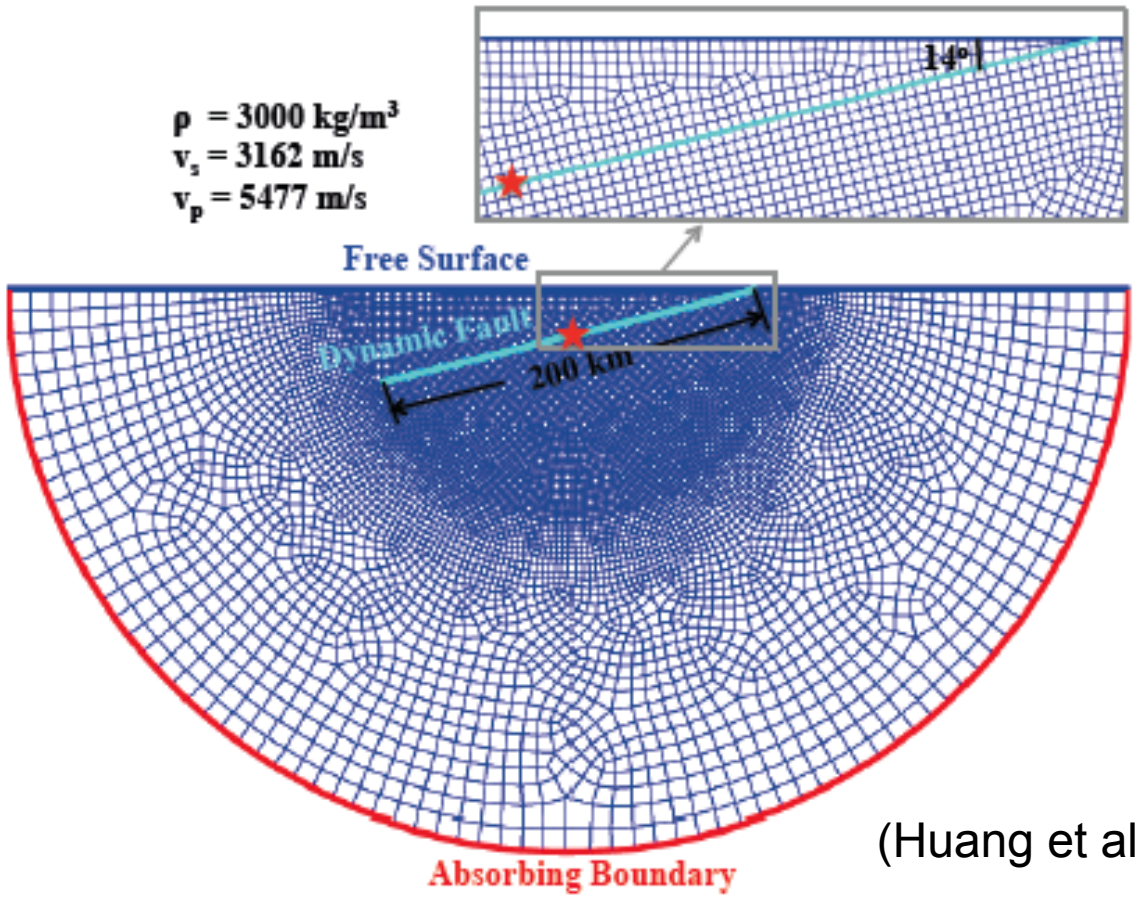
V.S.

Deeper region:

- Moderate slip;
- HF radiation;
- Rupture speed of ~ 1km/s.

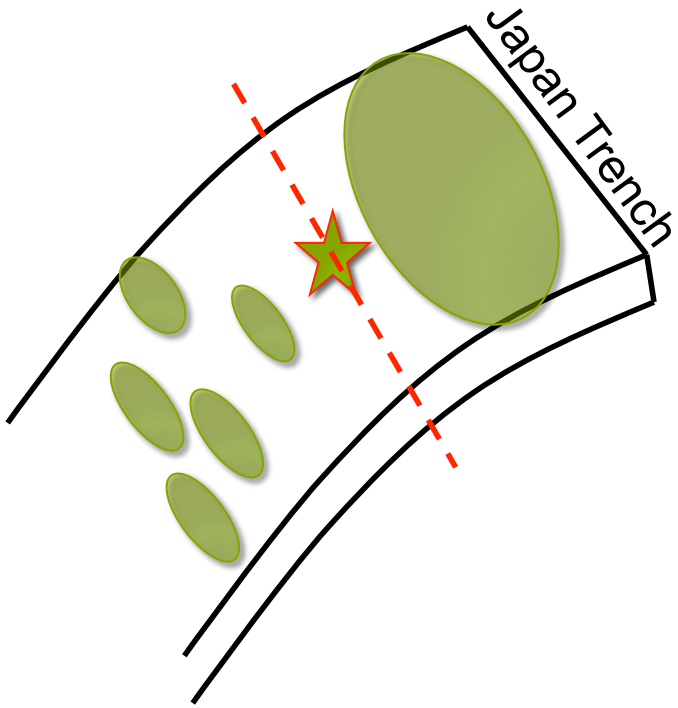
Small radiation efficiency

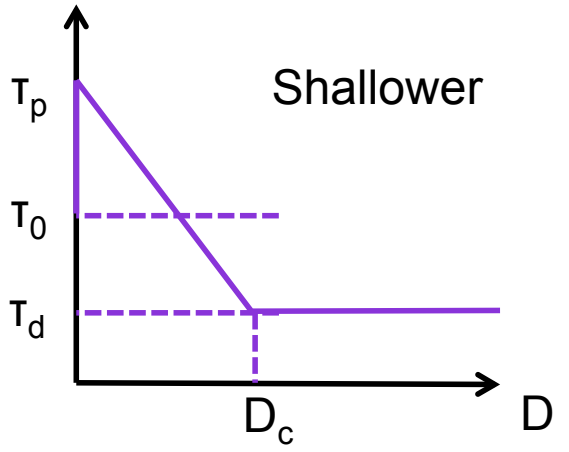
- We will focus on the down-dip process of the rupture. Thus, a 2D inplane model is enough.

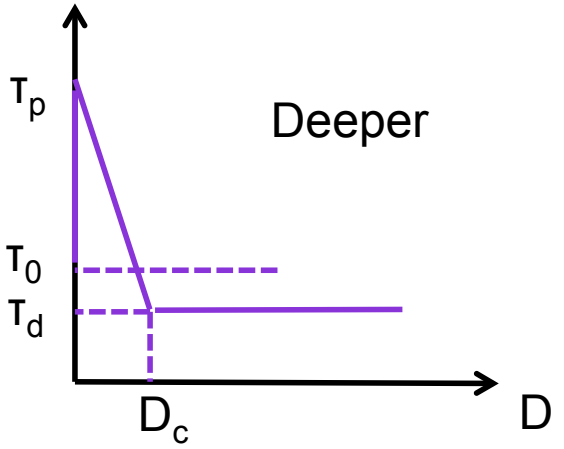


(Huang et al., EPS, 2012)

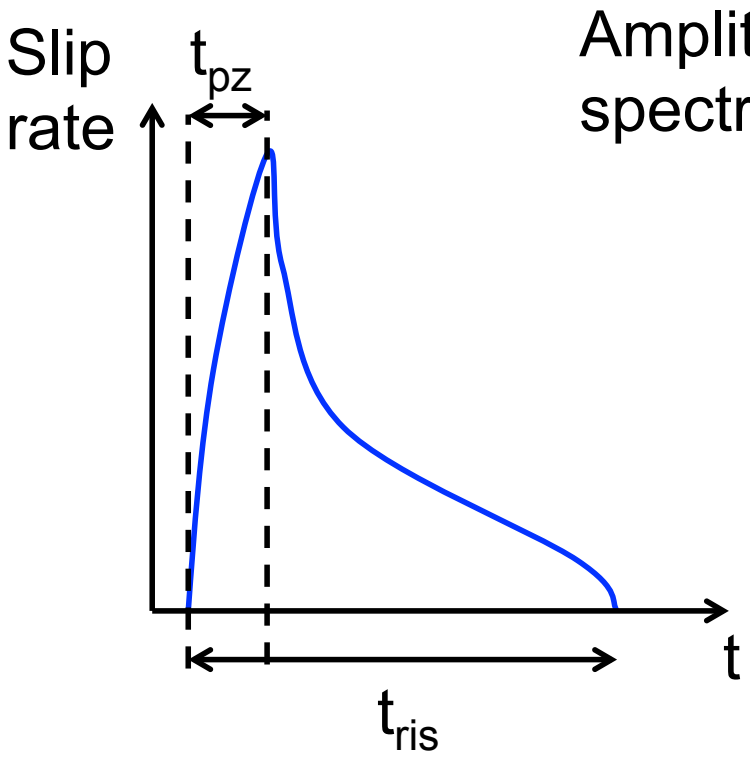
- The striking difference between shallower and deeper region suggests the existence of asperities.

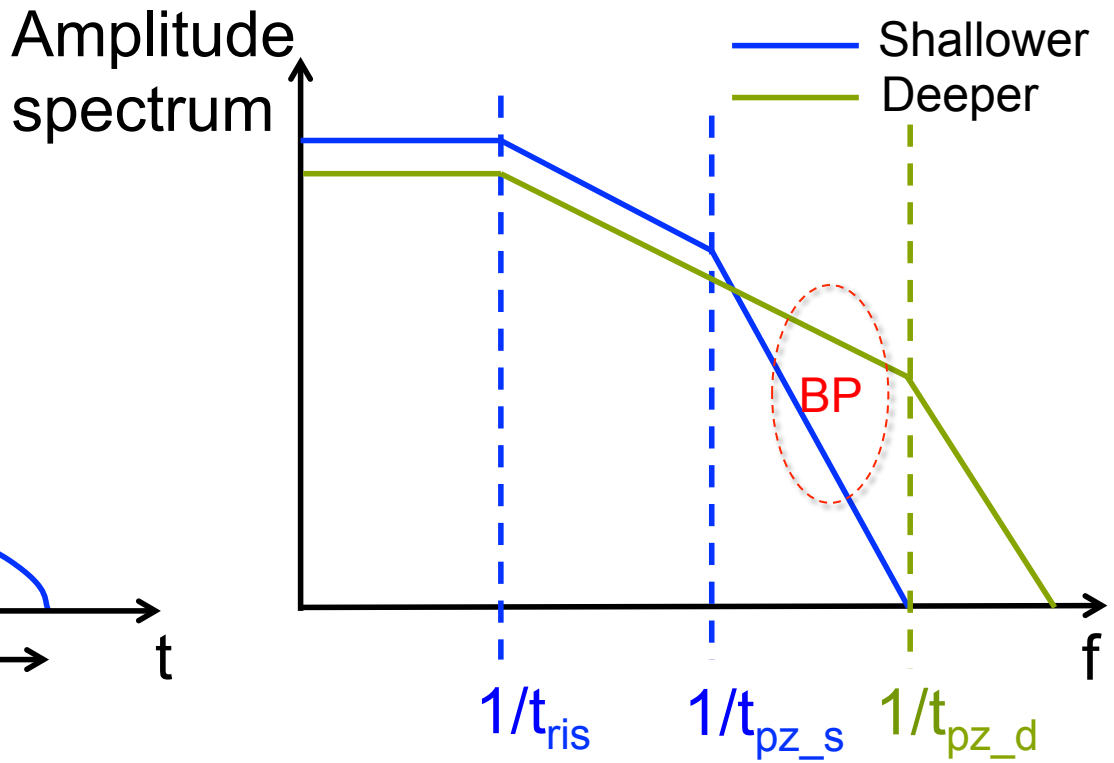






➢ How does Dc change the frequency content?

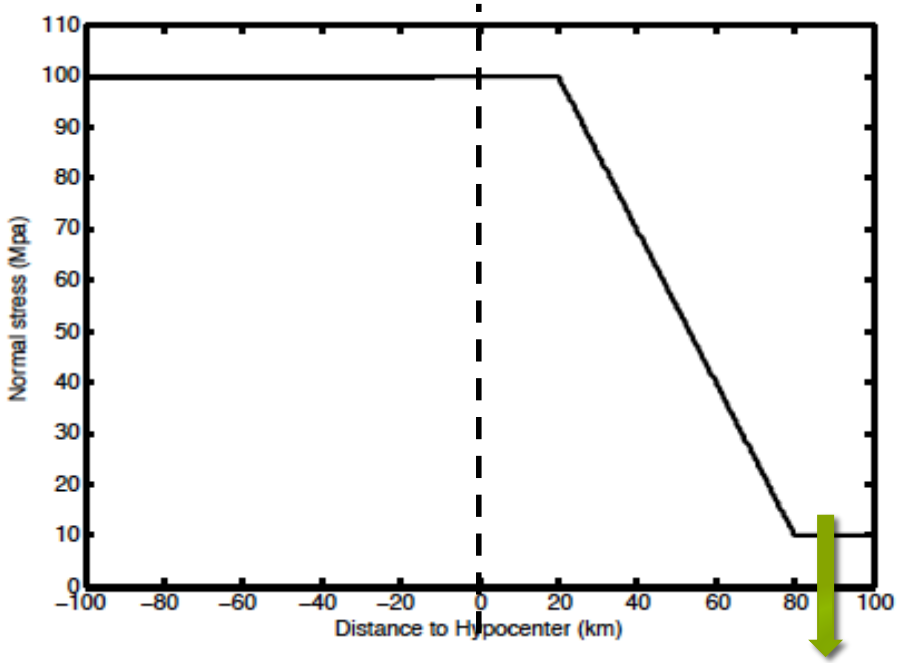




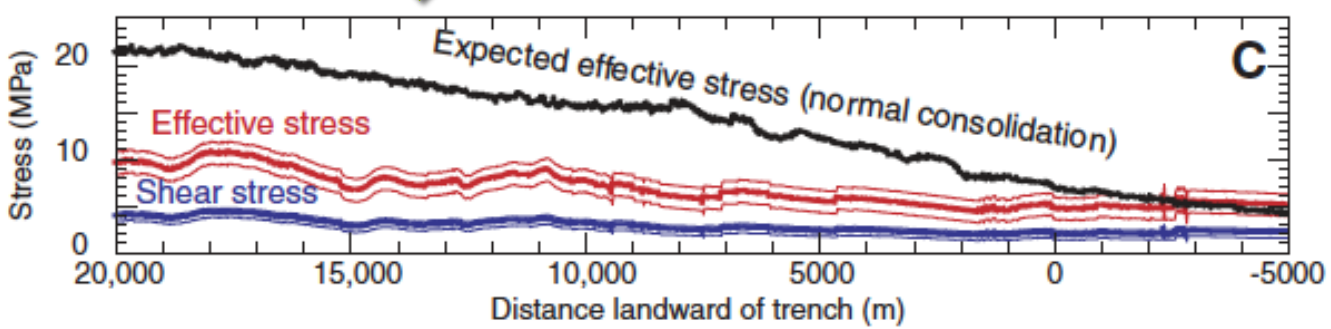
$$t_{pz}=L_c/v_r \approx \mu D_c/\Delta\tau_s v_r$$

$$1/t_{pz\_s} < 1\ \text{Hz} < 1/t_{pz\_d}$$

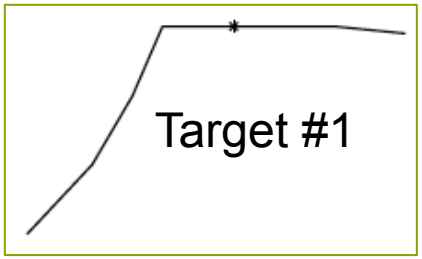
- We assume a certain distribution of normal stress.

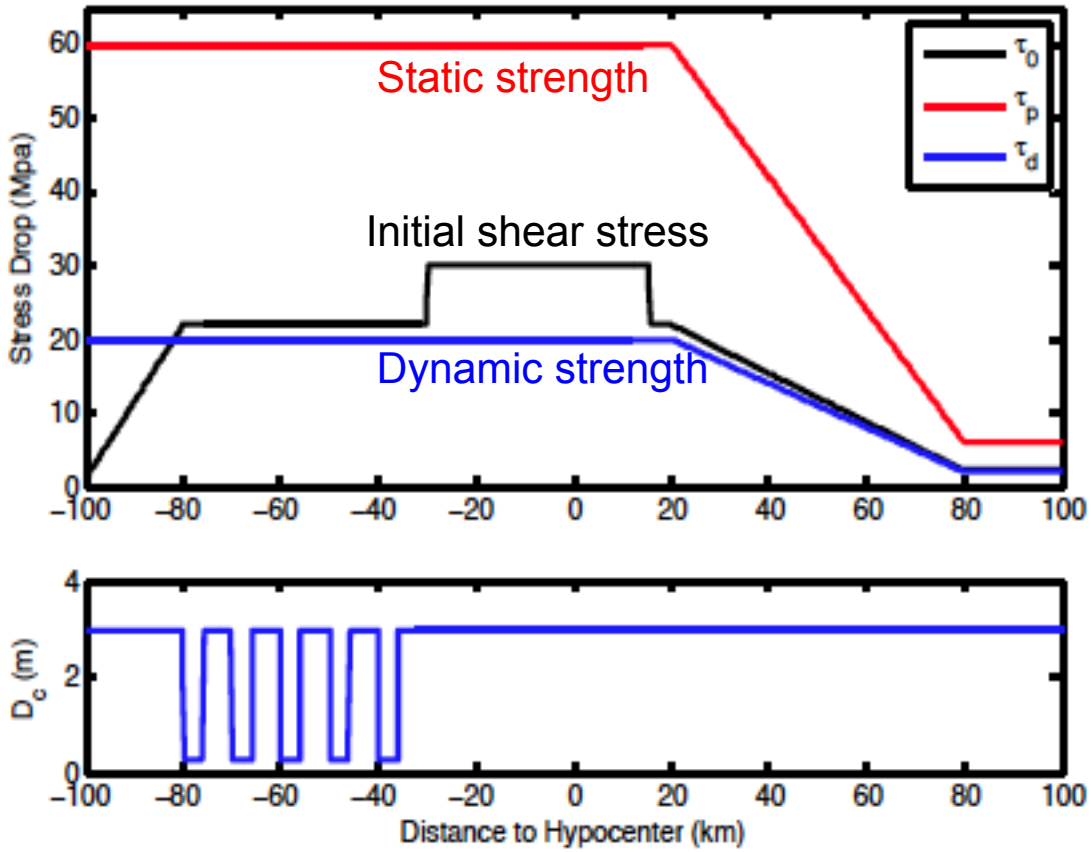


(Tobin and Saffer, 2009)

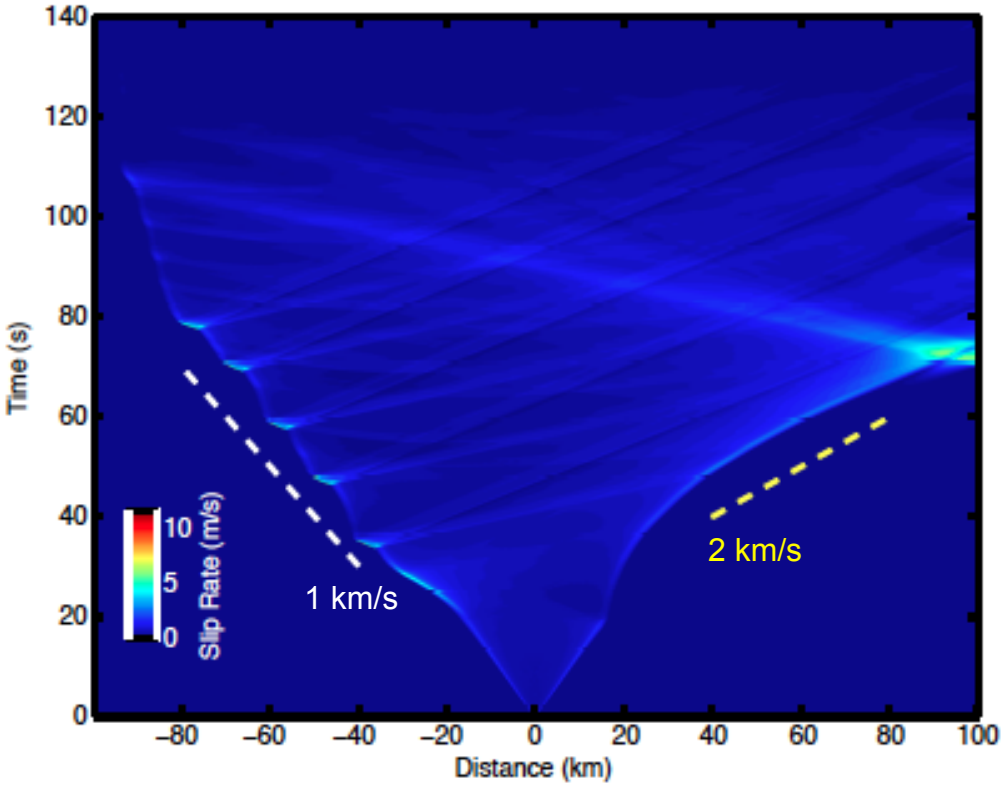


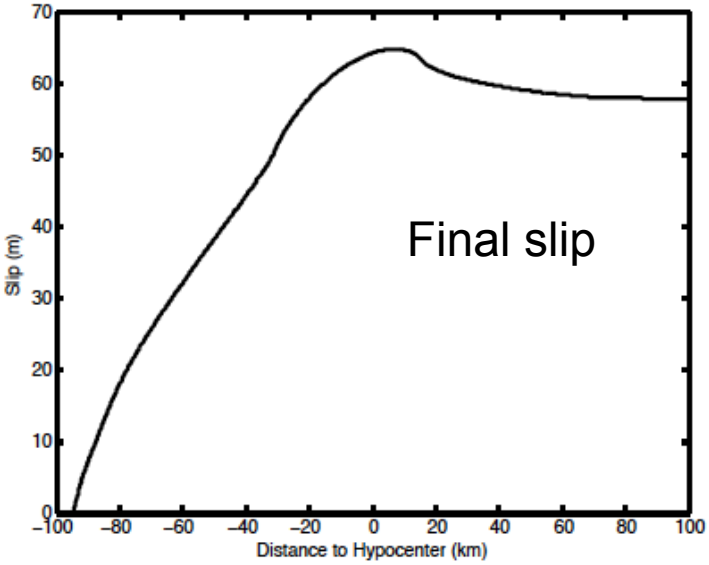
- Assuming constant friction coefficients, the only unknowns are initial stress and Dc, which are constrained by slip distribution and frequency contents.

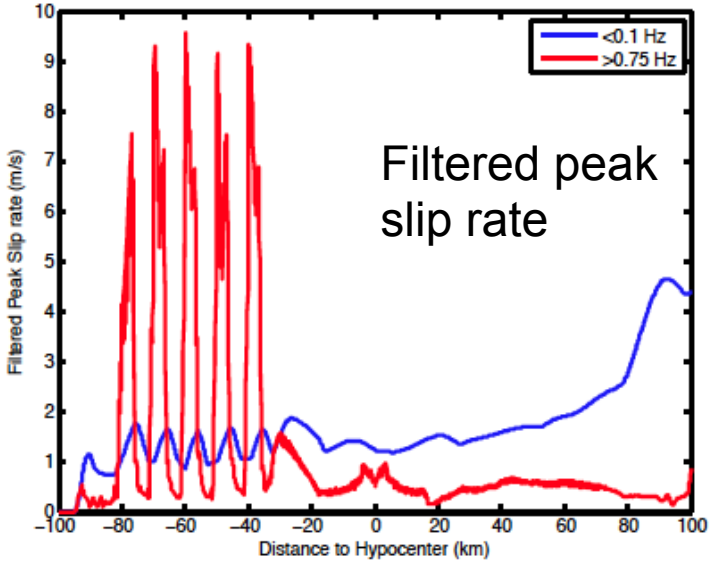




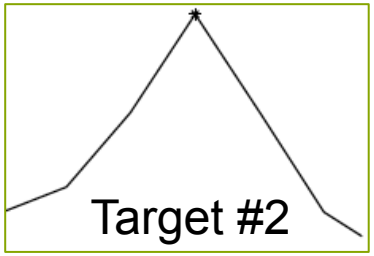
➢ Model #1's Output:

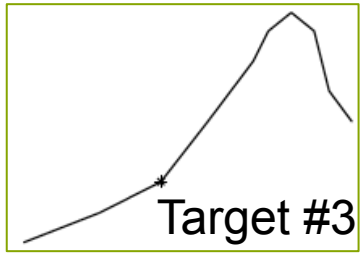


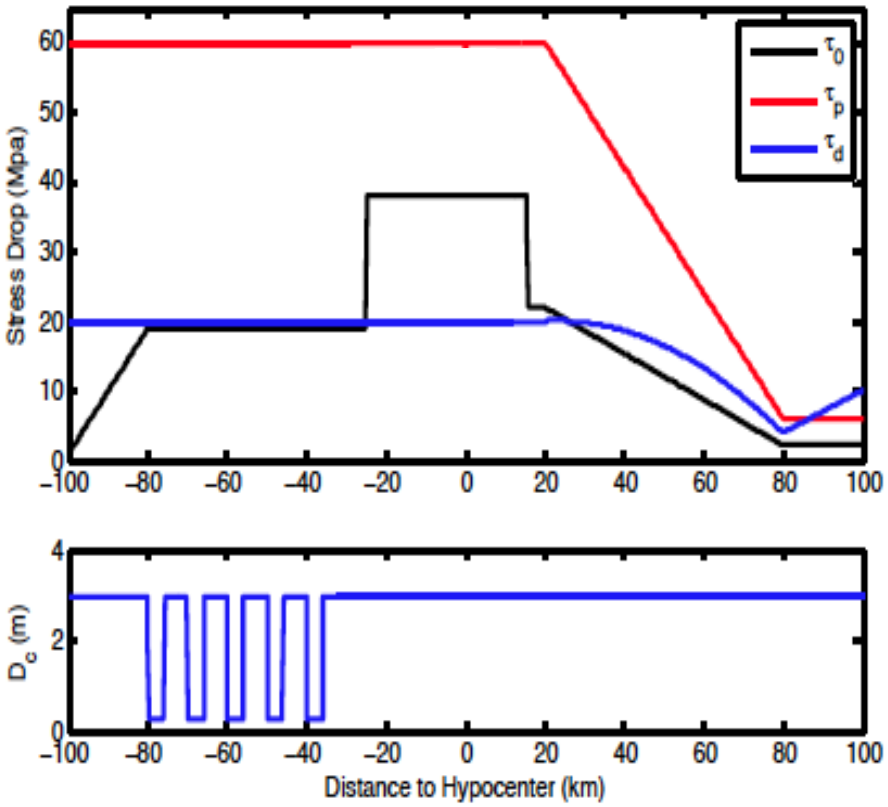


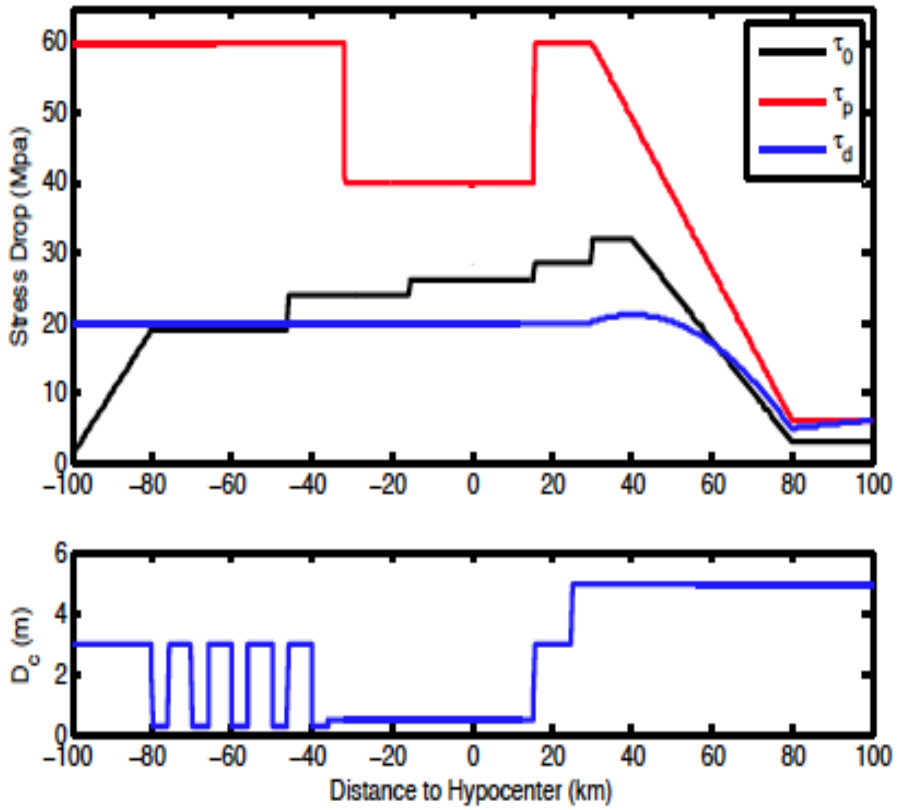


- The other two models:

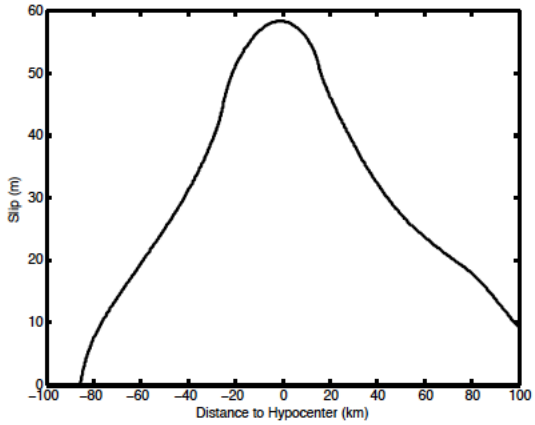


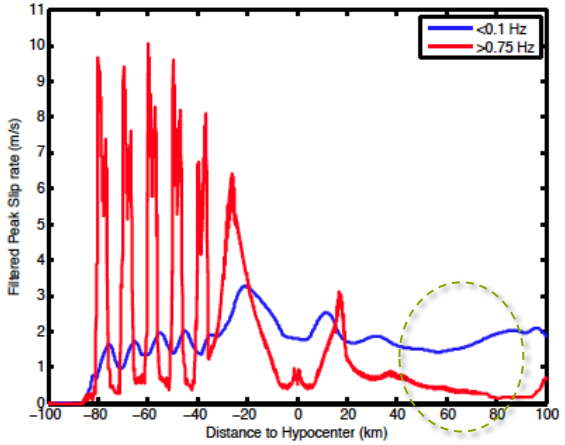


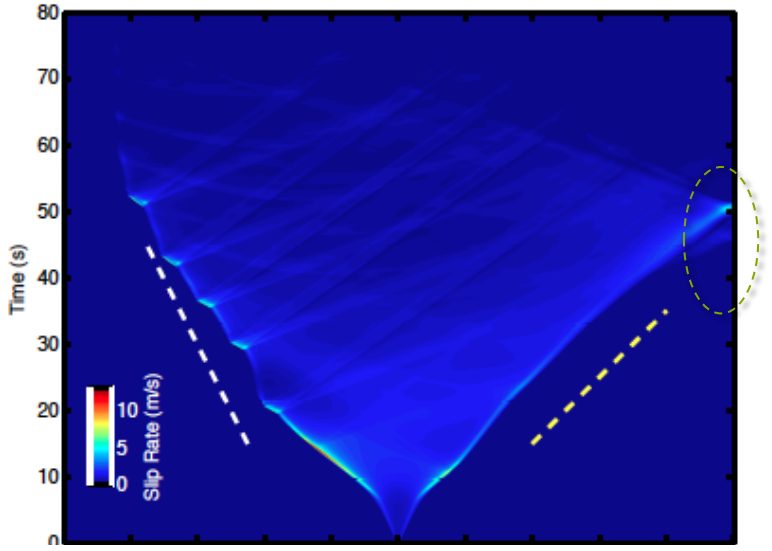


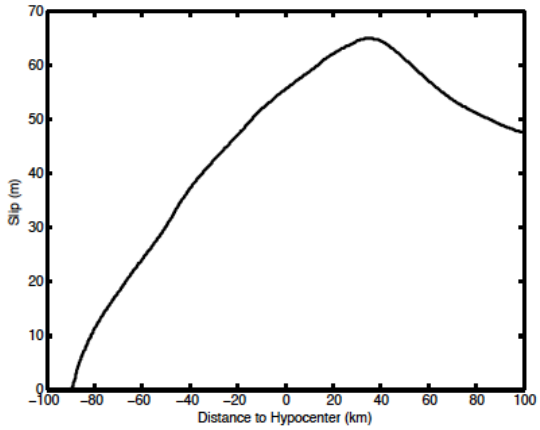


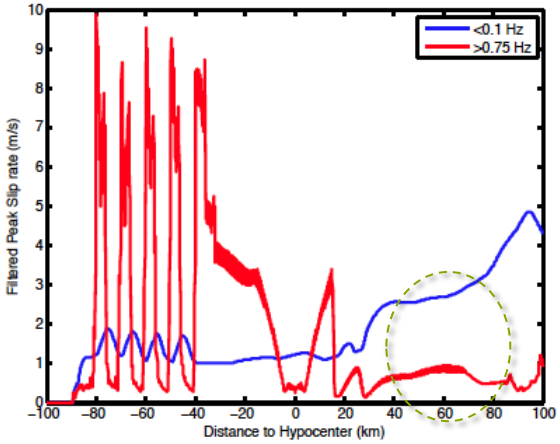
- The other two models' outputs:

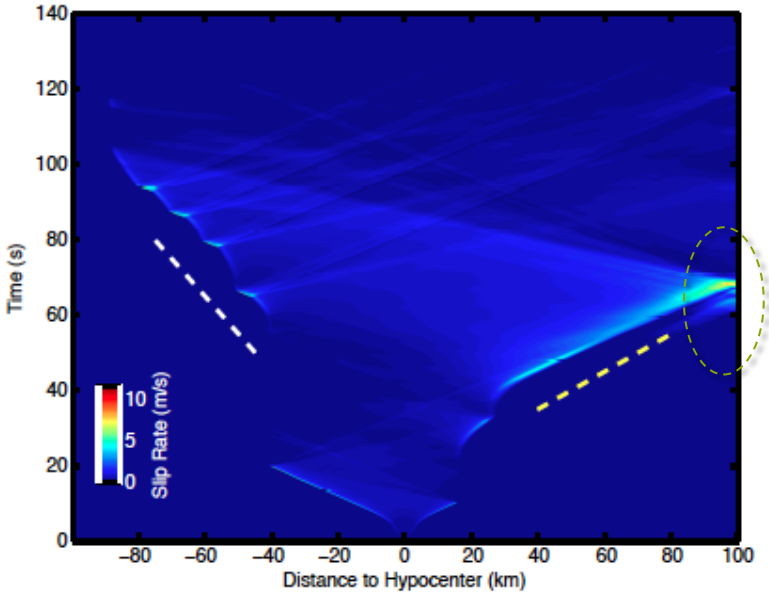






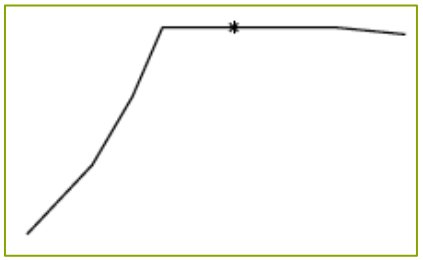




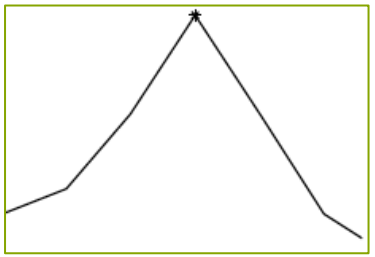


- Are the models consistent with most first-order observations?

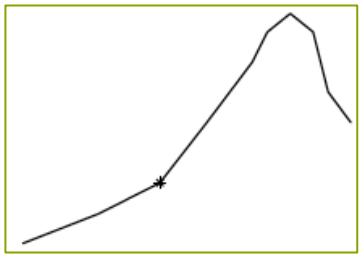
  - To some extent, yes. But they tend to overestimate the radiation efficiency.



$\eta_R = 0.33$



$\eta_R = 0.39$



$\eta_R = 0.50$

Conclusions

- The 2D slip-weakening model is enough to understand the along-dip rupture process.
- Model parameters are well-constrained by observations (not in an absolute level).
- Slip on the shallower region is still large when stress drop is very small or negative.
- Asperities of different Dc along down-dip directions facilitate HF bursts.