The 2014 M_w6.0 Napa Valley earthquake: Inversion for the parameters of the friction law

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Workshop NNEM2015

The calculation of synthetic data requires:

- a model of the system under investigation
- a physical theory linking the parameters of the model to the parameters being measured.

Predicting the observations, given a model, constitutes the "forward problem".

The "inverse problem" consists in using the actual observations to infer the parameters of the model that characterizes the system under investigation.

Tarantola, 2005

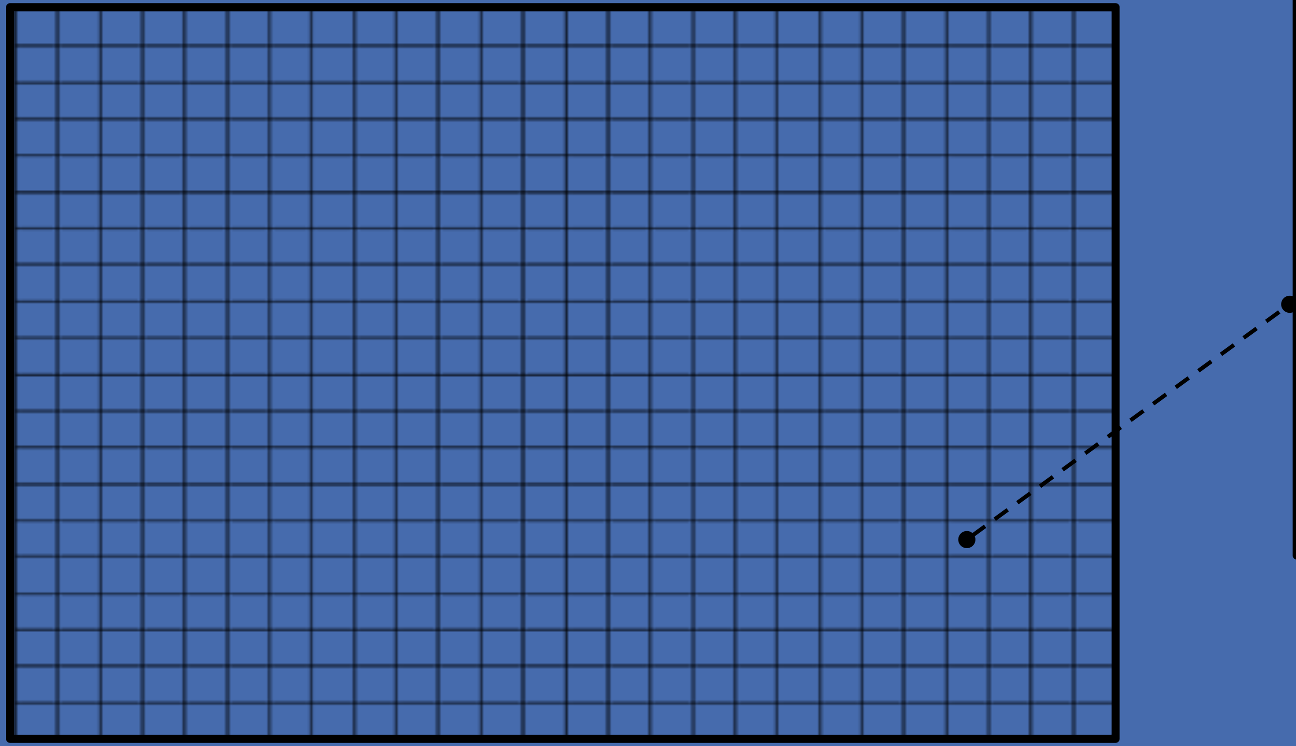
Finite-Fault inversion: Kinematic model

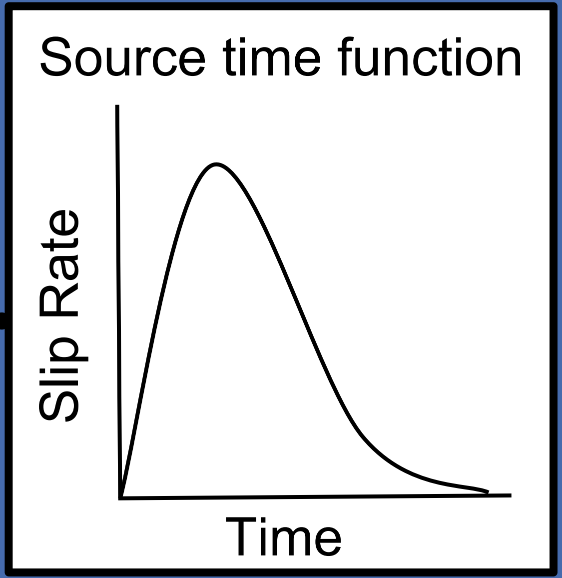
“The branch of mechanics concerned with the motion of objects without the reference to the forces which cause the motion”

Oxford Dictionary

Finite-Fault inversion: Kinematic model

Fault plane



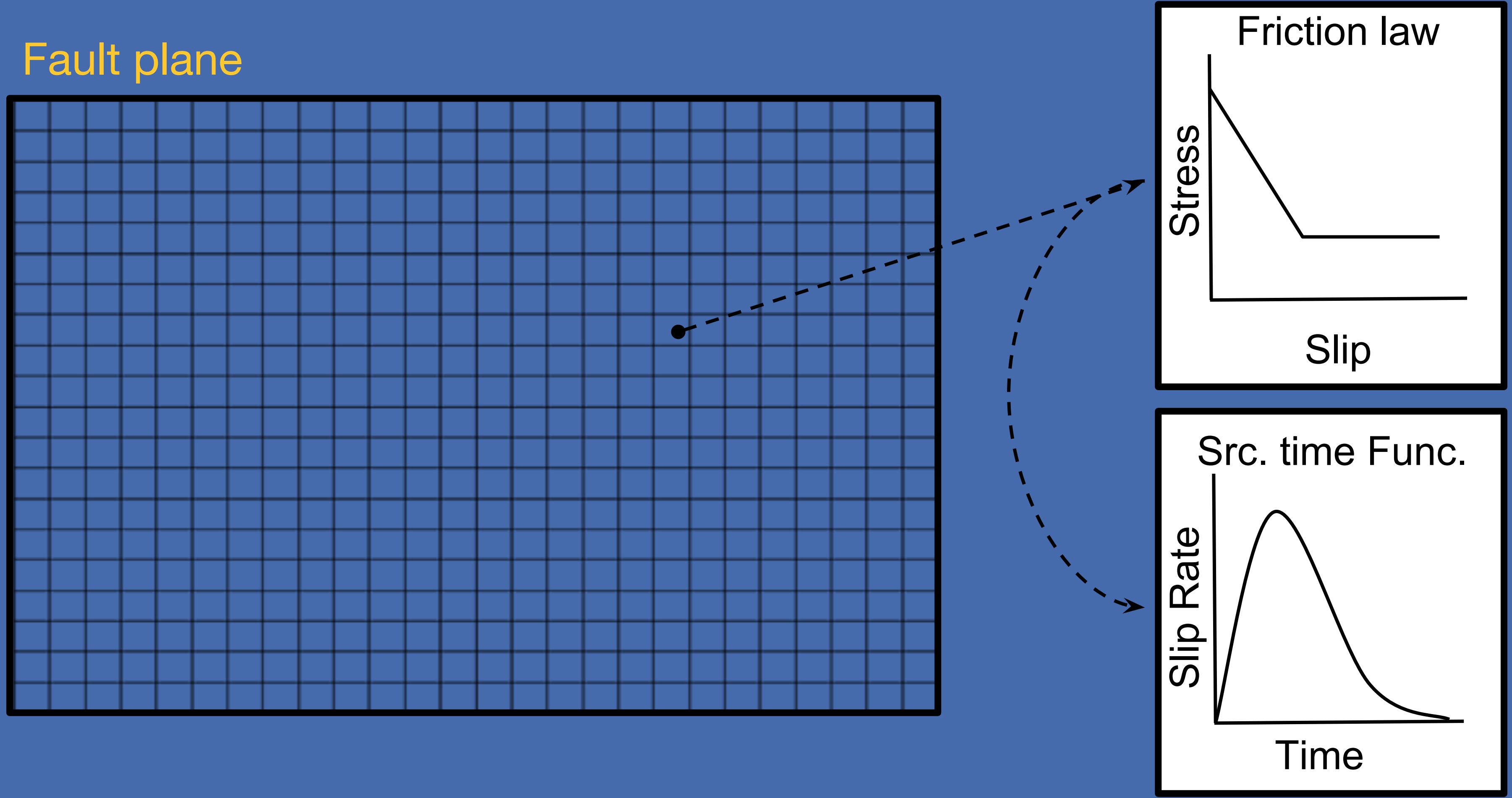


Finite-Fault inversion: Dynamic model

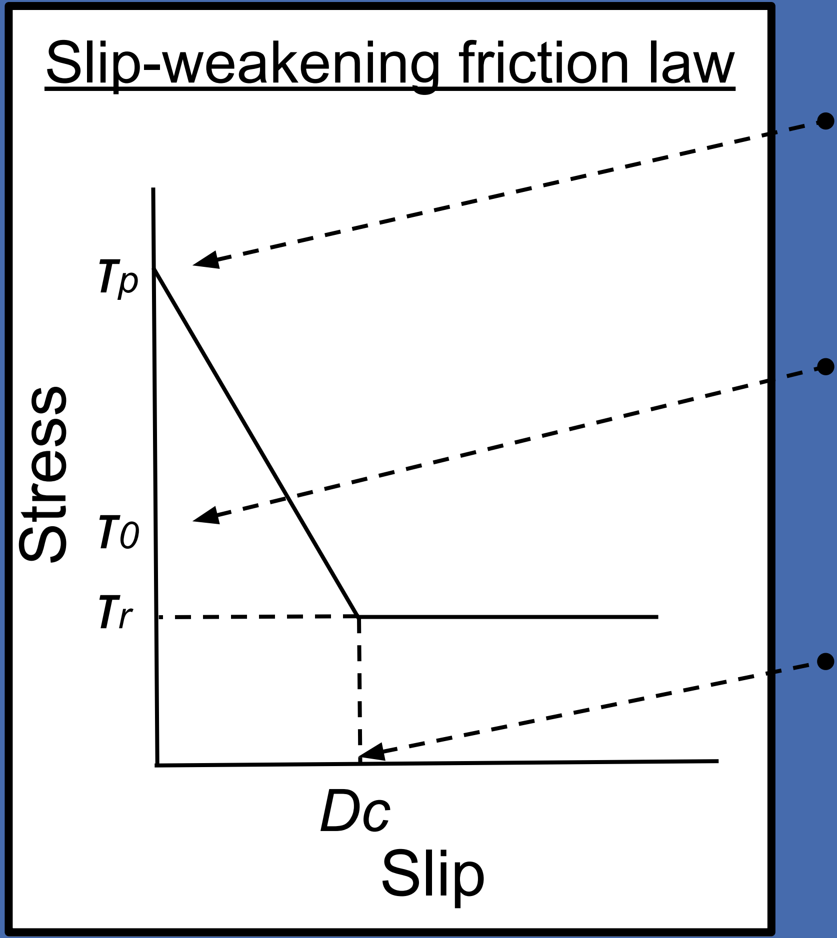
"The branch of mechanics concerned with the motion of bodies under the action of forces"

Oxford Dictionary

Finite-Fault inversion: Dynamic model



What do we invert for ? (1)



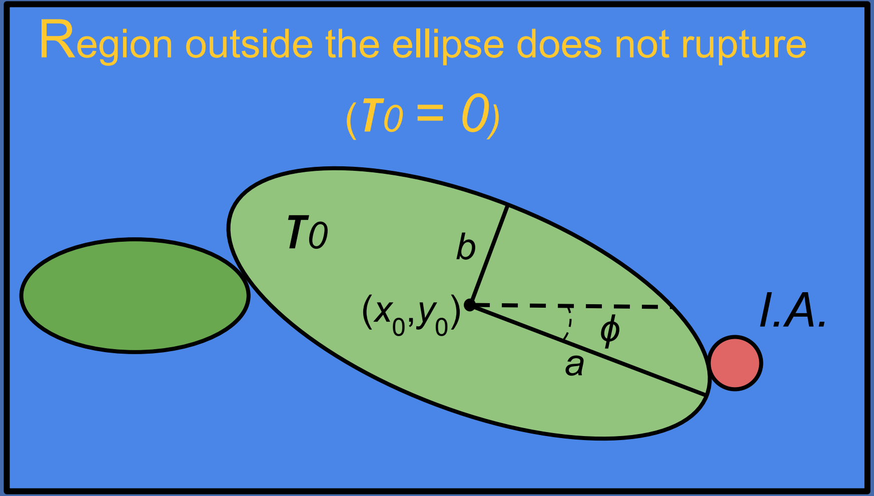
<u>Strength of the fault:</u>
The stress to overcome to start the rupture

<u>Background stress:</u>
The initial stress of the fault

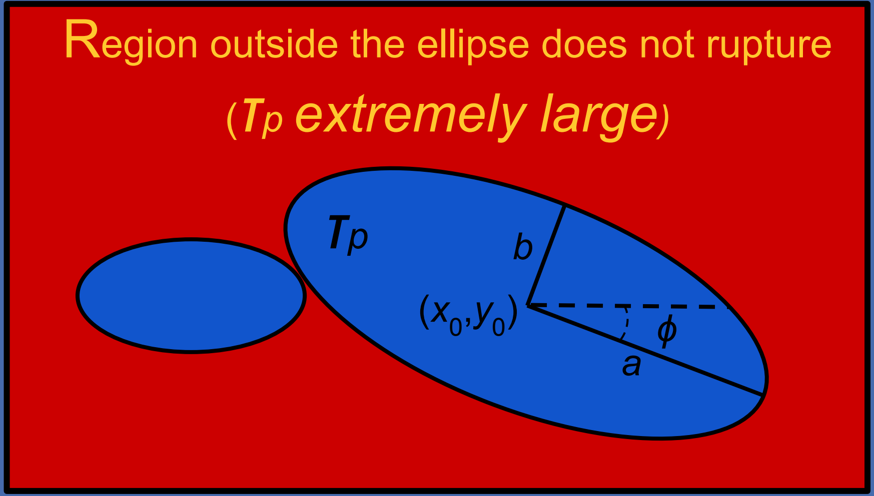
<u>Characteristic slip-weakening distance:</u>
The amount of slip required to slide at the residual stress level

What do we invert for ? (2)

Initial stress conditions



Strength



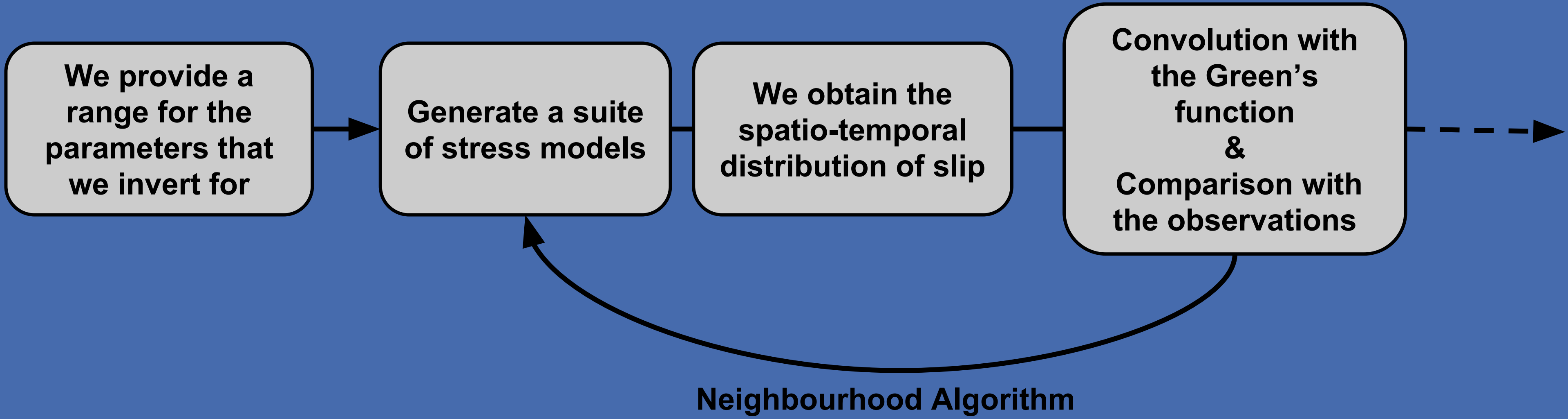
Geometry of the ellipse:

- location (x_0,y_0)
- size (a,b)
- orientation (ϕ)

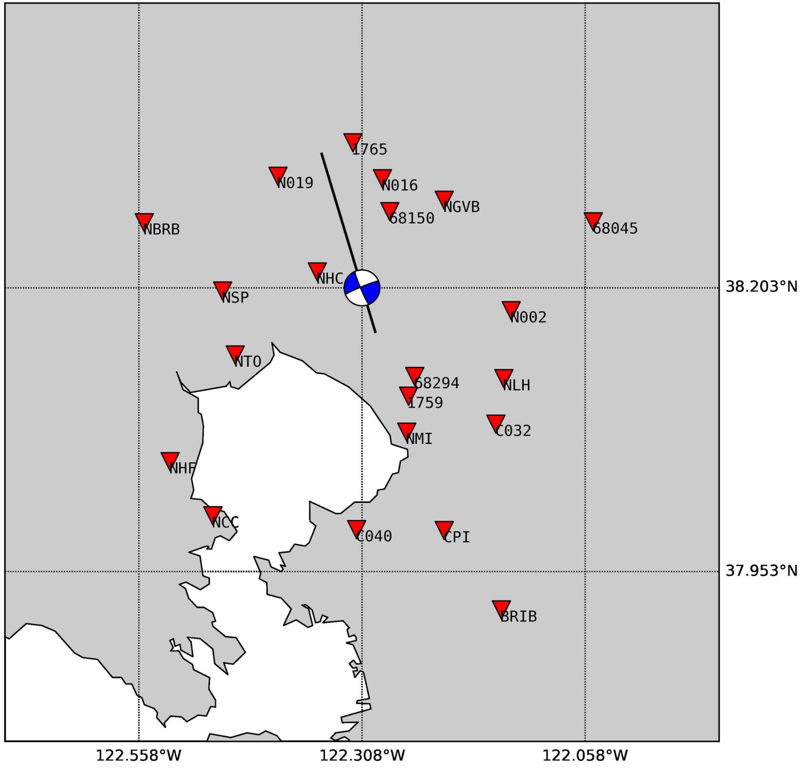
Initial asperity (I.A.):

- location (x_a,y_a)
- size (r_a)
- strength (τ_a)

Inversion procedure



The Napa Valley earthquake



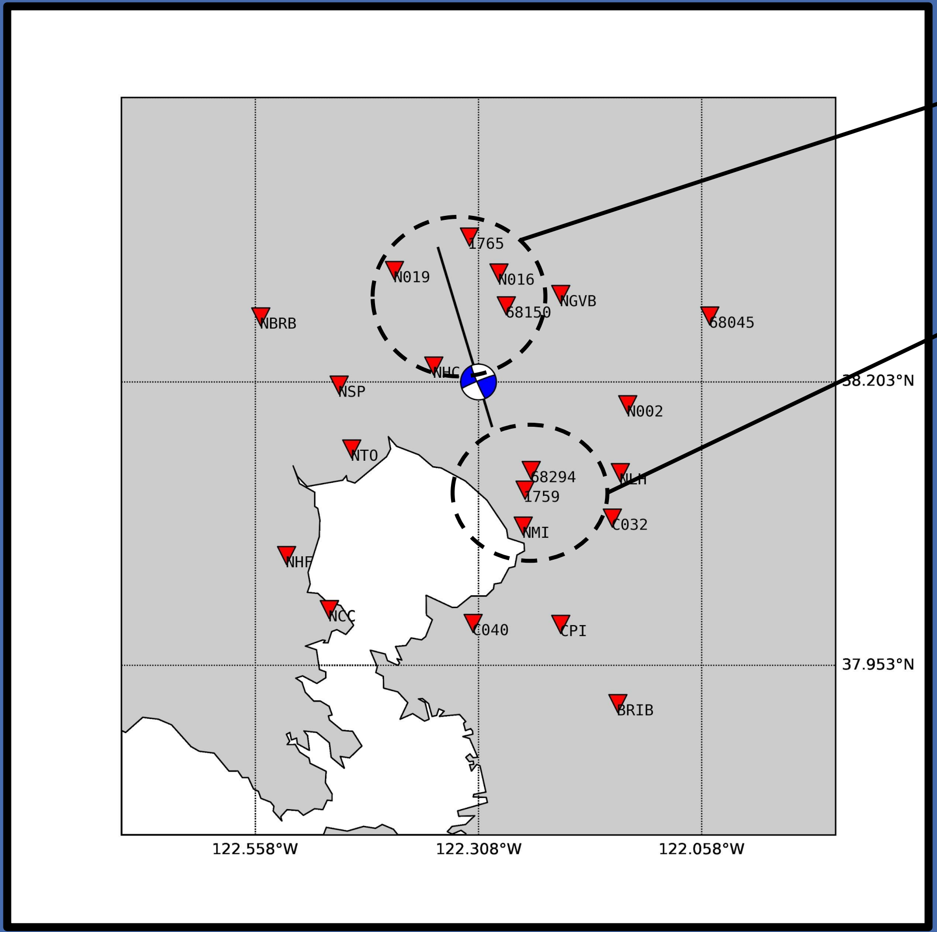
- 21 stations from the CGS, NCSN, and USGS network

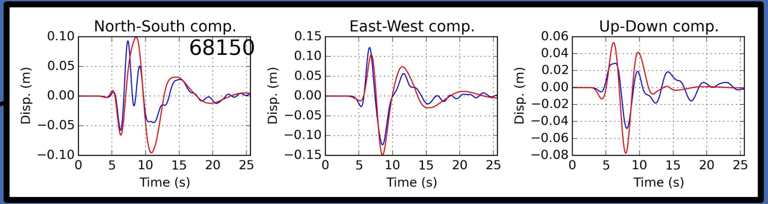
- The acceleration data are integrated twice into displacement

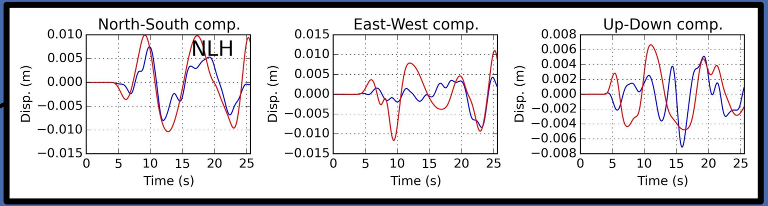
- The data are filtered between 0.1 and 0.5 Hz

- The fault plane:
18.5 km long and 11.5 km wide
strike: N159°, dip: 87°, rake: 180°

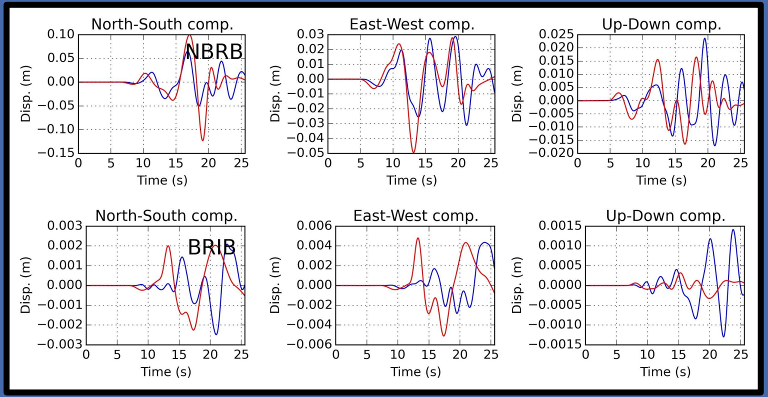
Best fitting model: fit to the stations



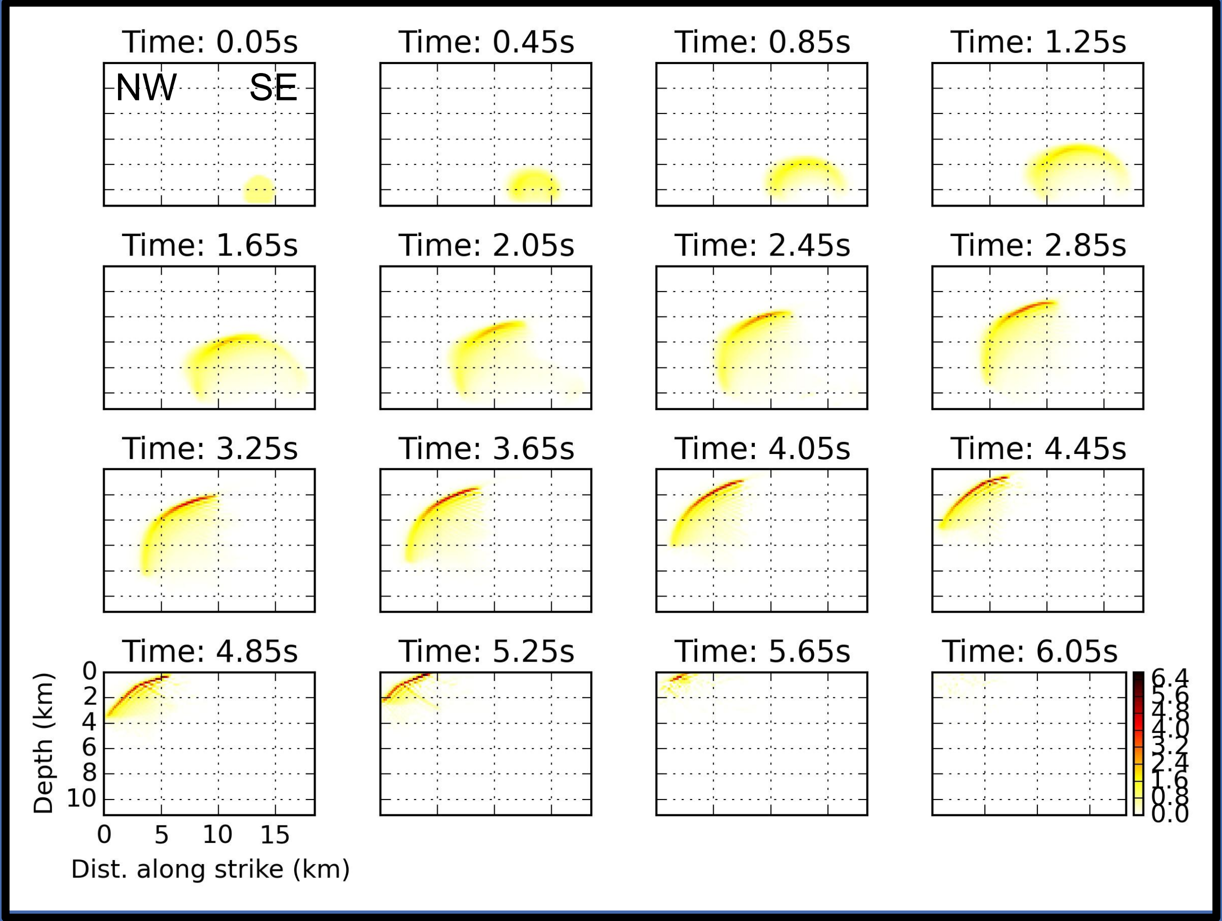




Distant stations



Best fitting model: rupture process

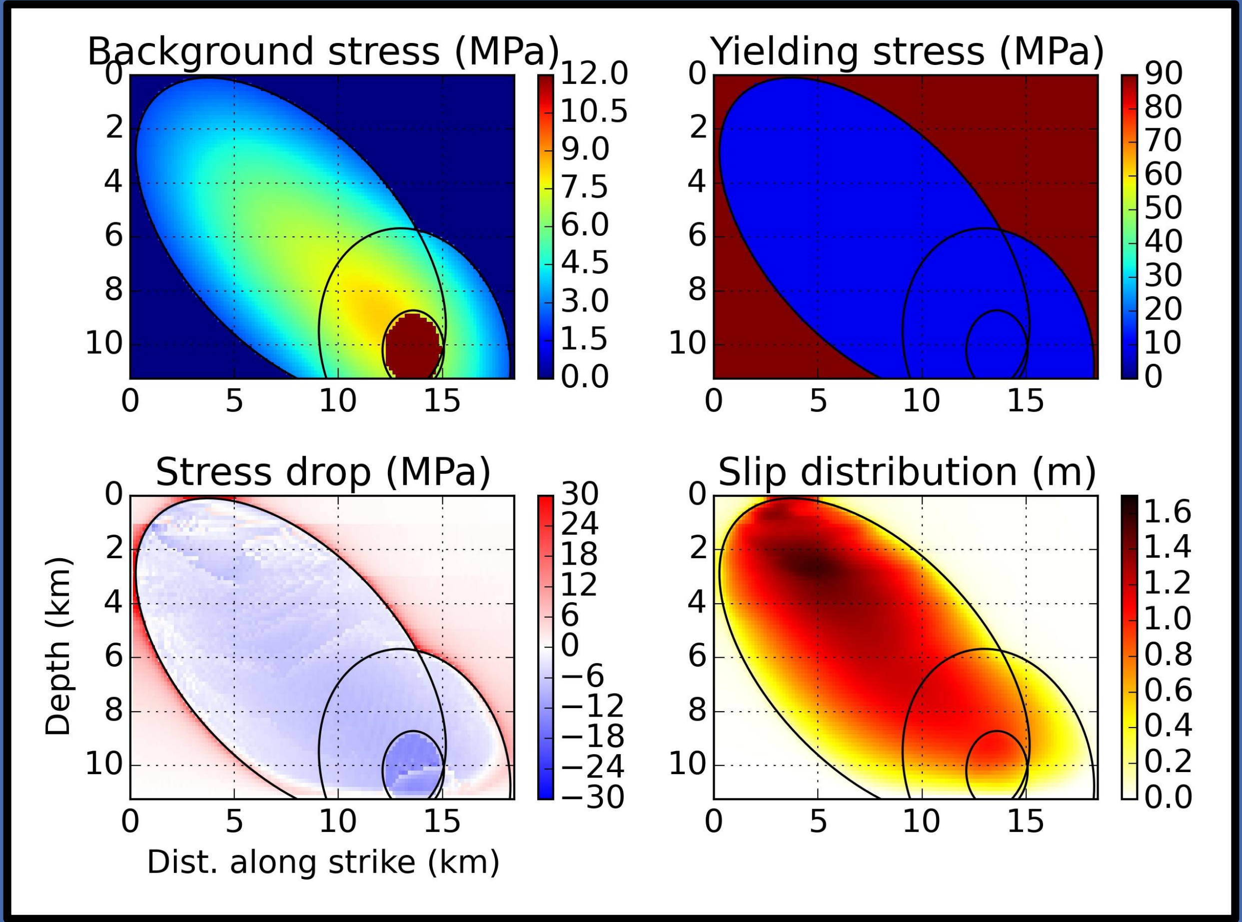


<u>Phase #1:</u>
bilateral rupture propagation at depths between 6 to 11 km for the first ~1.6 sec.

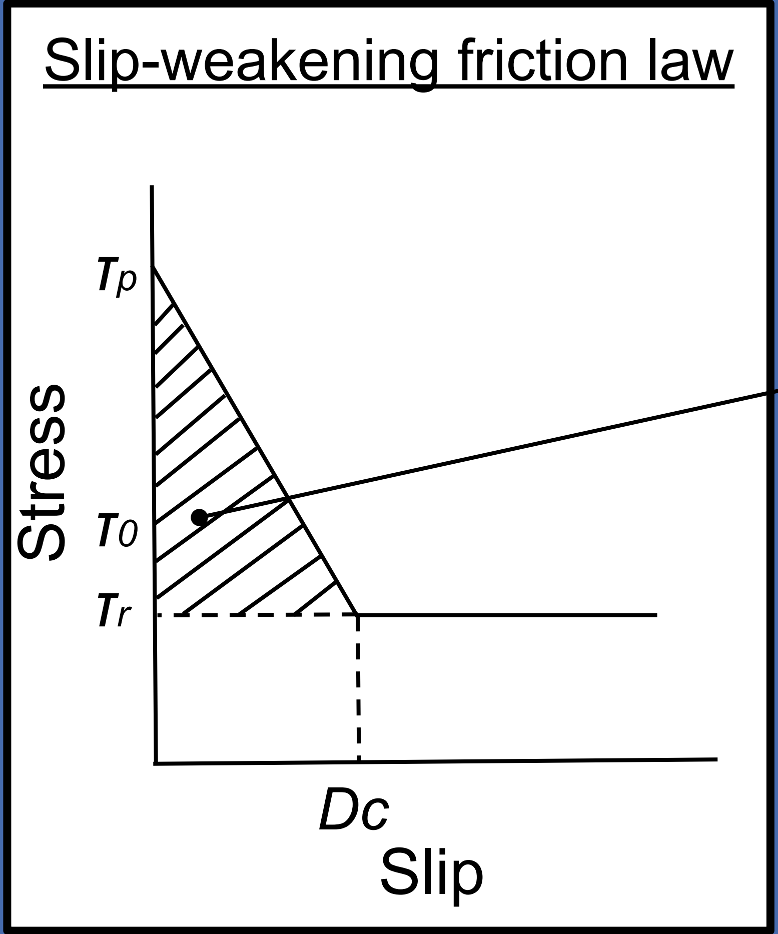
<u>Phase #2:</u>
oblique up-dip rupture propagation from 1.6 to 6 sec. after which the rupture dies out.

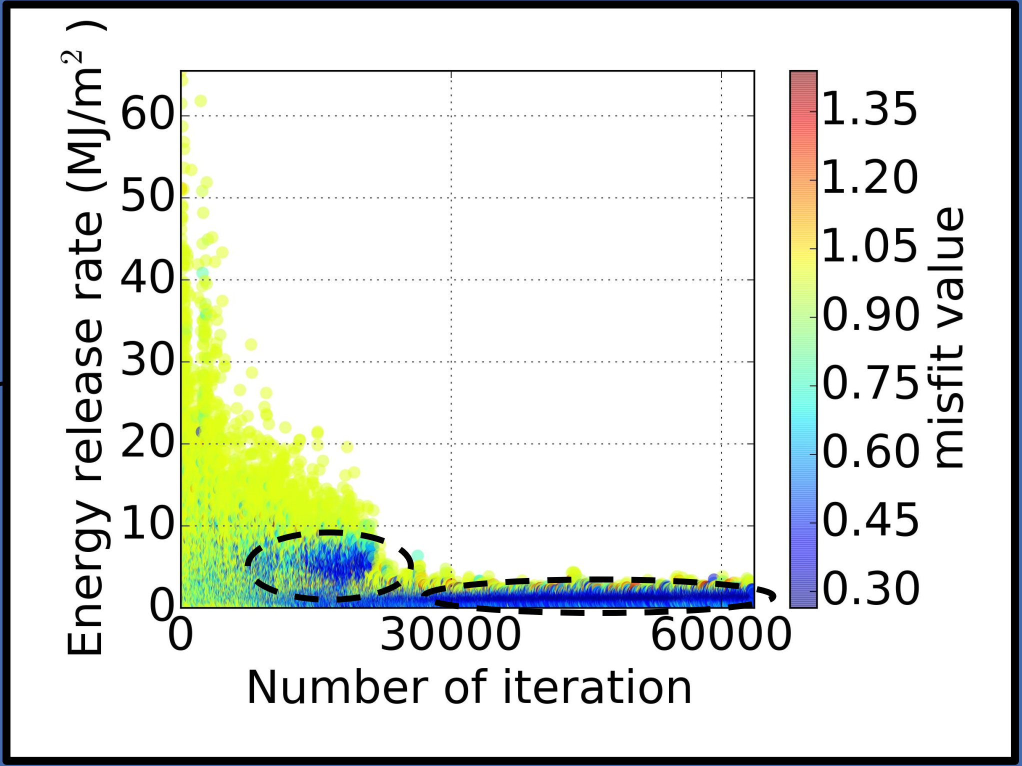
The overall rupture progresses at ~3 km/s

Best fitting model: initial conditions and final distributions



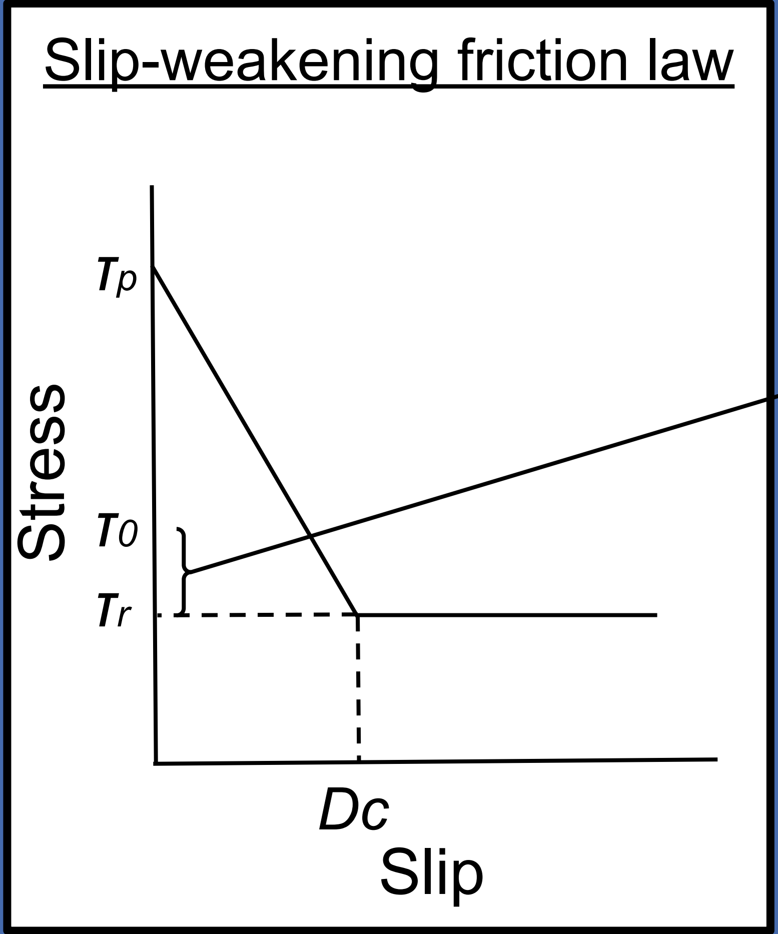
What have we learnt about the friction (1)

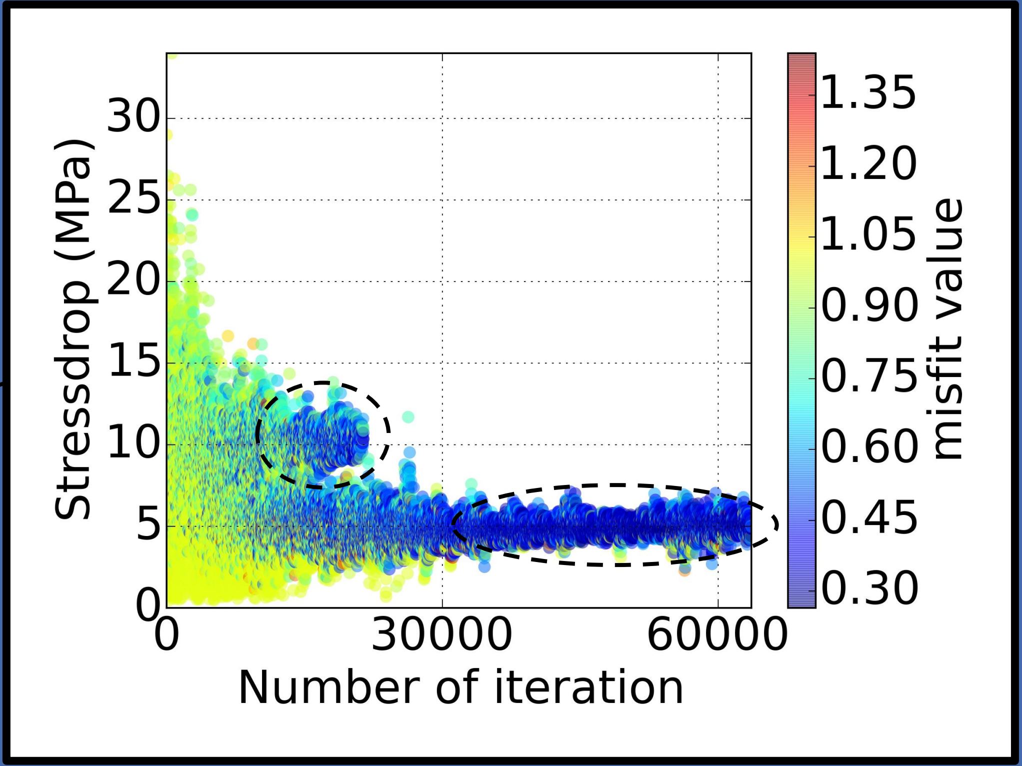




For misfit ≤ 0.3: [0.5 - 6.0]
Best fitting value: 1.0 MJ/m^2

What have we learnt about the friction (2)





For misfit ≤ 0.3: [3.0 - 10.0]
Best fitting value: 5 MPa

Criticality of the rupture

$$G = \frac{1}{2}\tau_p D_c$$

- Rupture resistance

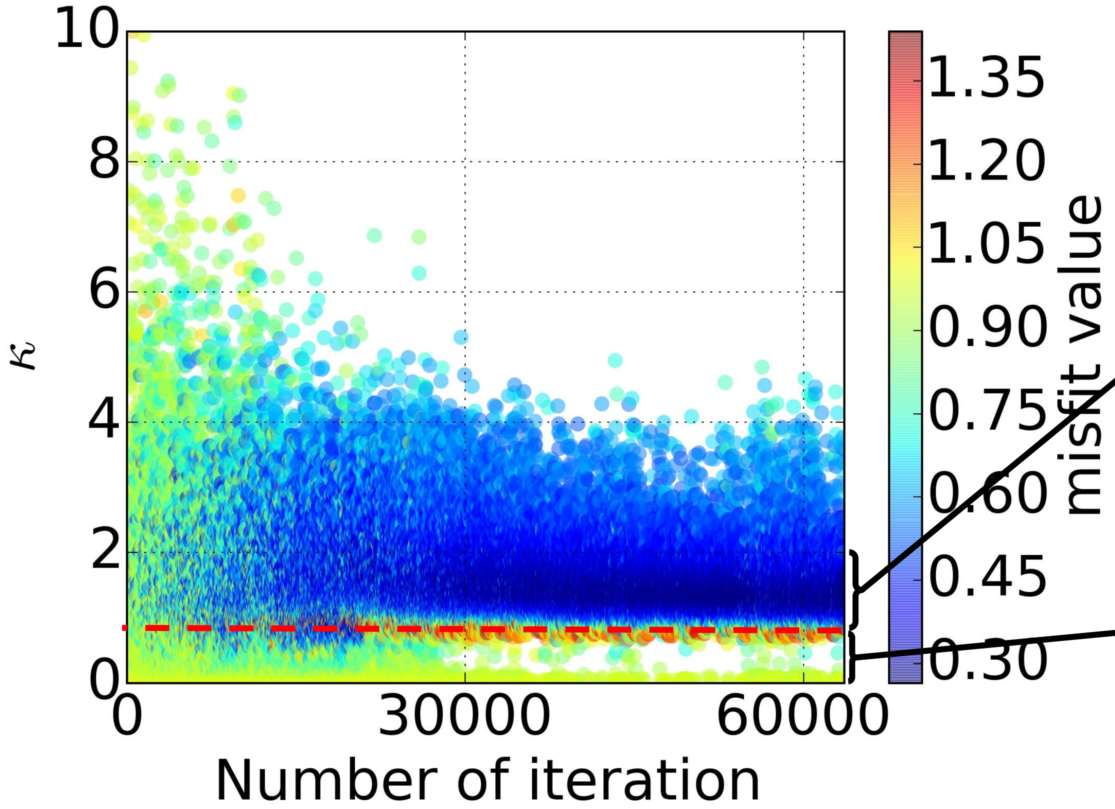
$$\Delta U = \frac{1}{2}\langle D\rangle \tau_0$$

- Strain energy change per unit fault surface

$$\kappa \simeq \Delta U / G$$

- $\kappa < \kappa_c$ - Rupture doesn't grow
- $\kappa > \kappa_c$ - Rupture grows sub-shear
- $\kappa \gg \kappa_c$ - Rupture grows super-shear

Criticality of the rupture



$$\kappa \simeq \Delta U / G$$

For misfit ≤ 0.3: [0.8-2.0].

Best fitting value: 1.0

Regions where the rupture does not grow: **κ** ≲ 0.6

Conclusions

- It is possible to invert for the parameters of the friction law. Thus, we can use observations to constrain these parameters and gain insight into rupture dynamics

- The inversion allows us to explore a wide range of dynamic models and thus investigate the different stress conditions under which we can get a model that fits the observed data.