大大特：動力学パラメータの研究
動力学モデルの強震動への応用

⌘ **動力学モデルの導入法**

（2通りの方法）

- 震源過程・強震動同時シミュレーション
- 動力学モデルの近似式

Dynamic modeling

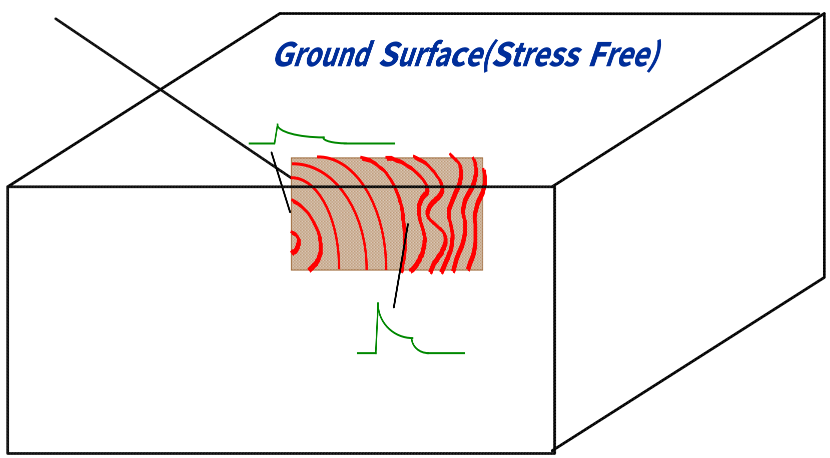
Stress release process whether rupture is spontaneous or not.

Dynamic problem in Local area

- Fault constitutive law

$$\tau = f(\Delta u, \frac{\partial \Delta u}{\partial t}, \theta, T, \ldots)$$

If τ> τ p or t>Tr(x,z)



Absorbing Boundary Condition

$$\rho\frac{\partial v_1}{\partial t} = \frac{\partial \tau_{11}}{\partial x_1} + \frac{\partial \tau_{12}}{\partial x_2} + \frac{\partial \tau_{13}}{\partial x_3}$$

$$\rho\frac{\partial v_2}{\partial t} = \frac{\partial \tau_{21}}{\partial x_1} + \frac{\partial \tau_{22}}{\partial x_2} + \frac{\partial \tau_{23}}{\partial x_3}$$

$$\rho\frac{\partial v_3}{\partial t} = \frac{\partial \tau_{31}}{\partial x_1} + \frac{\partial \tau_{32}}{\partial x_2} + \frac{\partial \tau_{33}}{\partial x_3}$$

$$\frac{\partial \tau_{11}}{\partial t} = (\lambda + 2\mu)\frac{\partial v_1}{\partial x_1} + \lambda\frac{\partial v_2}{\partial x_2} + \lambda\frac{\partial v_3}{\partial x_3}$$

$$\frac{\partial \tau_{22}}{\partial t} = \lambda\frac{\partial v_1}{\partial x_1} + (\lambda + 2\mu)\frac{\partial v_2}{\partial x_2} + \lambda\frac{\partial v_3}{\partial x_3}$$

$$\frac{\partial \tau_{33}}{\partial t} = \lambda\frac{\partial v_1}{\partial x_1} + \lambda\frac{\partial v_2}{\partial x_2} + (\lambda + 2\mu)\frac{\partial v_3}{\partial x_3}$$

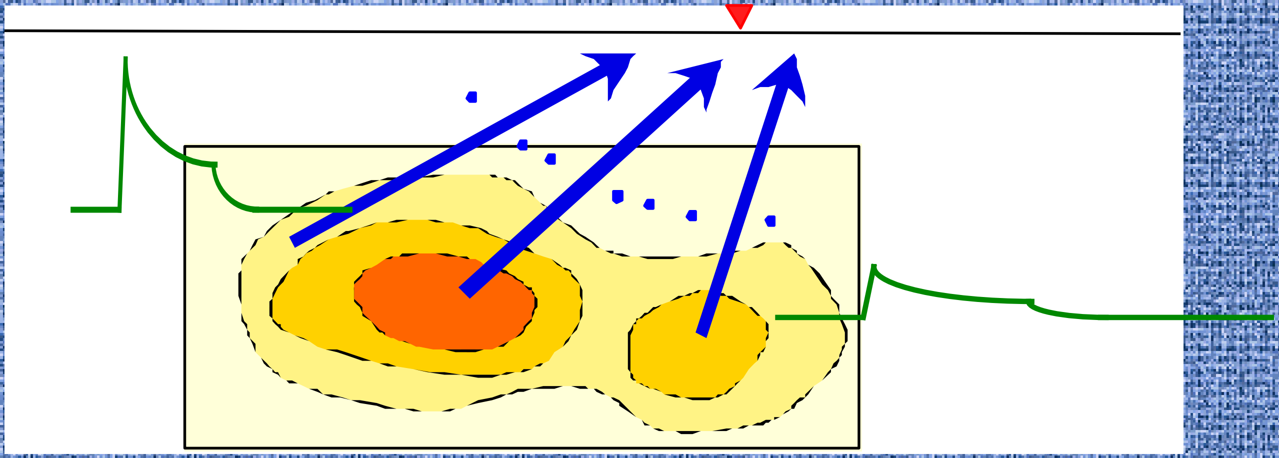
$$\frac{\partial \tau_{12}}{\partial t} = \mu\left(\frac{\partial v_1}{\partial x_2} + \frac{\partial v_2}{\partial x_1}\right)$$

$$\frac{\partial \tau_{13}}{\partial t} = \mu\left(\frac{\partial v_1}{\partial x_3} + \frac{\partial v_3}{\partial x_1}\right)$$

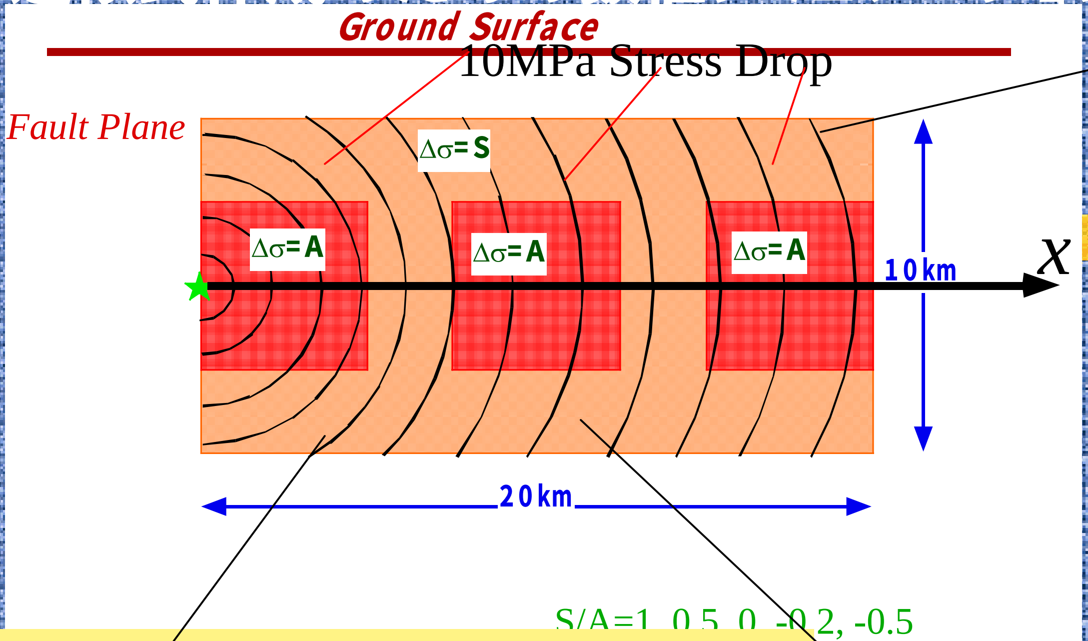
$$\frac{\partial \tau_{23}}{\partial t} = \mu\left(\frac{\partial v_2}{\partial x_3} + \frac{\partial v_3}{\partial x_2}\right)$$

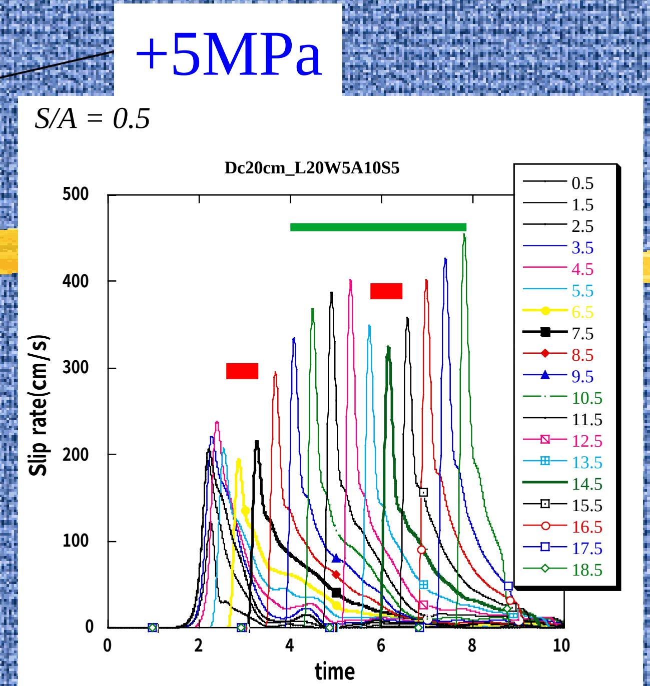
すべり速度時間関数の近似式

- 2 approaches
  - FD (or FEM) Simulation of Dynamic Faulting process
  - Seismic wave from slip time history based on dynamic source model
    - Approximate expression of slip rate time function for dynamic rupture

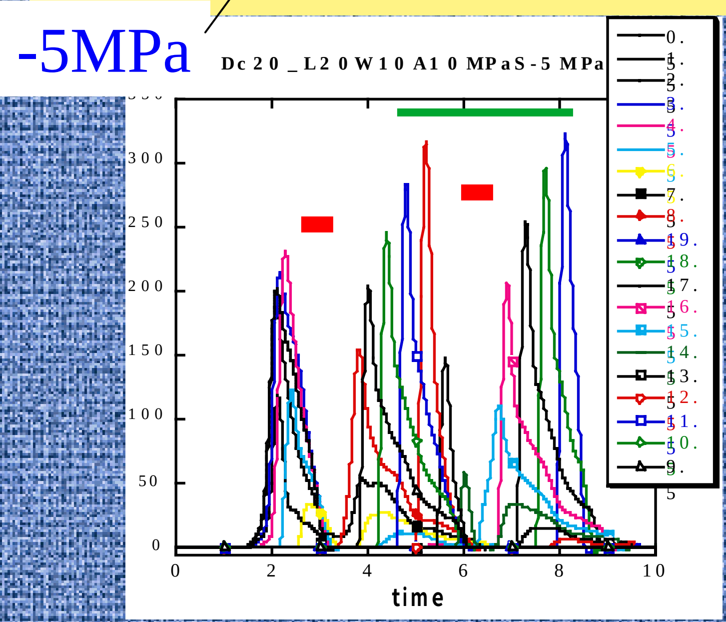


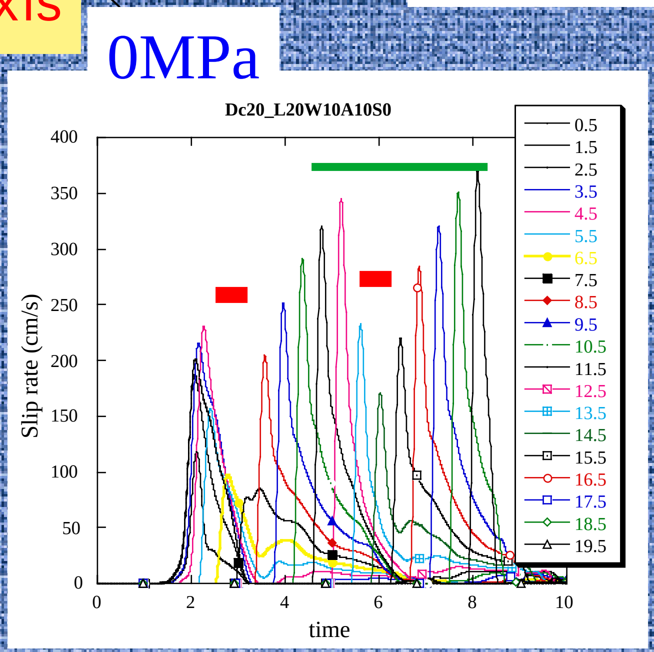
近似式作成のための数値シミュレーション



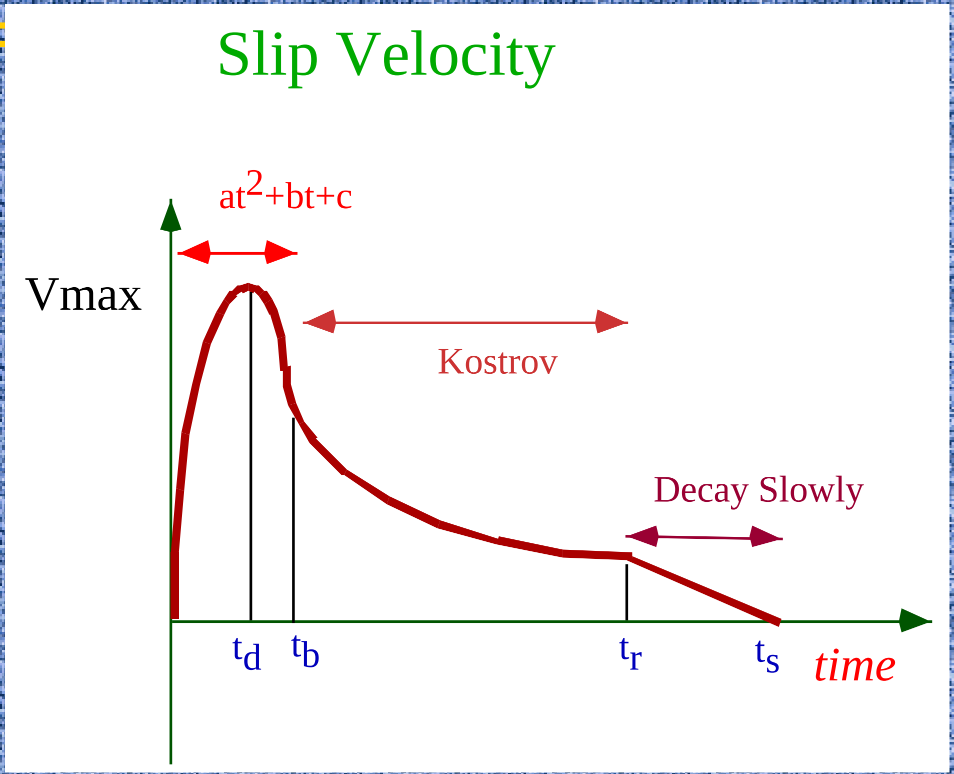


Slip rate time history along x-axis



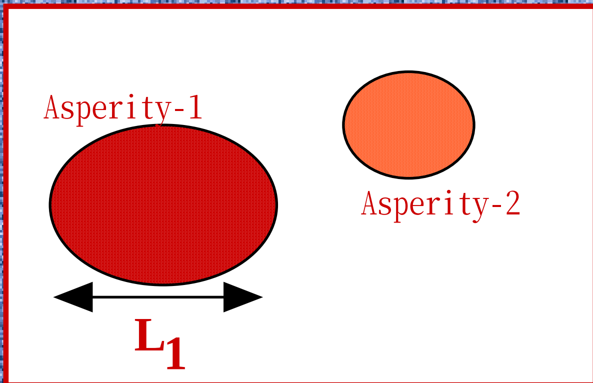


近似式



- パラメータ
  Vm, td, tb, tr, ts
- 必要な情報
  - Vm (又は$\Delta\sigma$)
  - td(又はfmax)
  - すべり量
  - ライズタイム

パラメータの決め方



Asperity

Location	
Size	L
Stress Drop	ΔσÅ@

L

Δσ

Rise time　tr = L/2Vr,　ts 〜1.5 tr

$$V_m \approx \frac{\Delta\sigma\sqrt{2LV_R f_C}}{\mu}$$

Δσ=5MPa〜20MPa

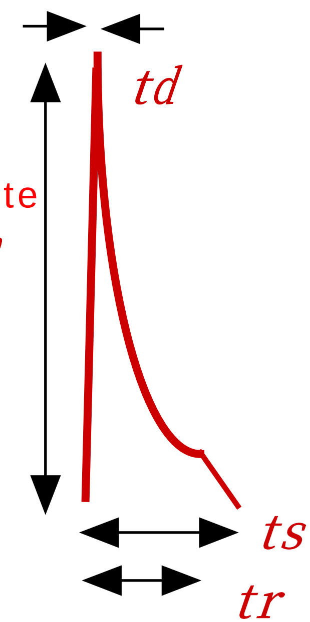
fc〜fmax

Lowpassfiltered peak slip rate

fc:cutoff frequency

Day(1982)

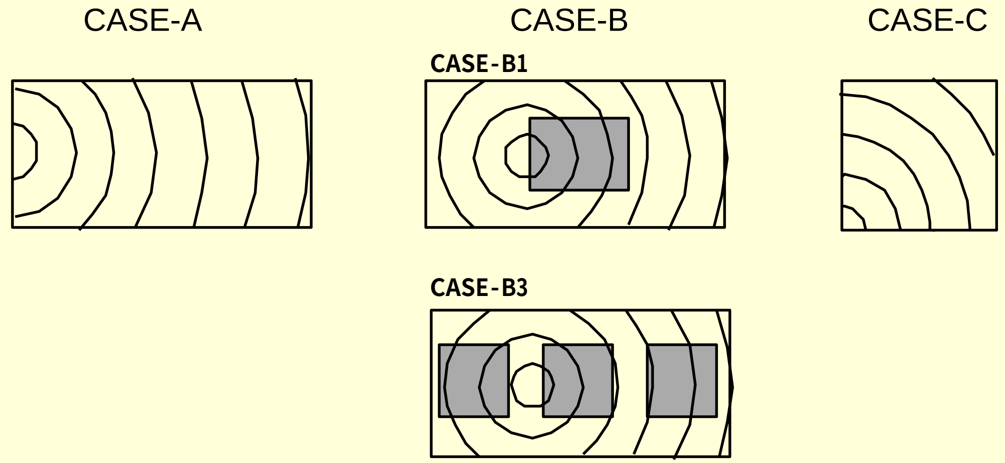
td 〜0.2



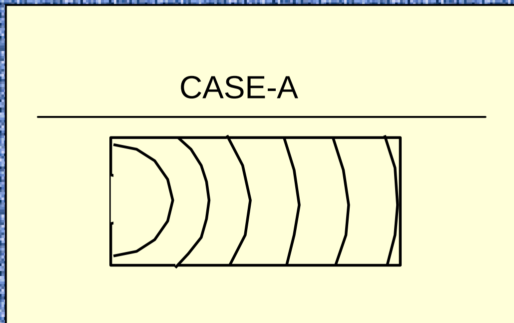
Application of the approximate expression of slip rate time function to strike slip fault

CASES

Shallow Strike Slip Fault

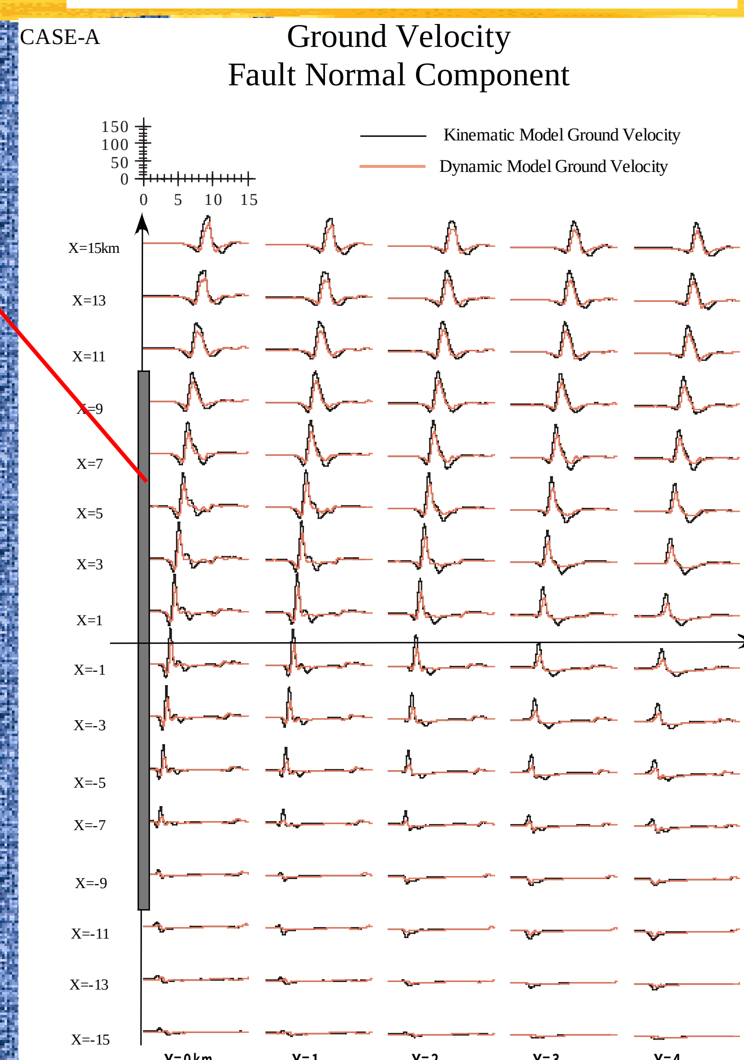


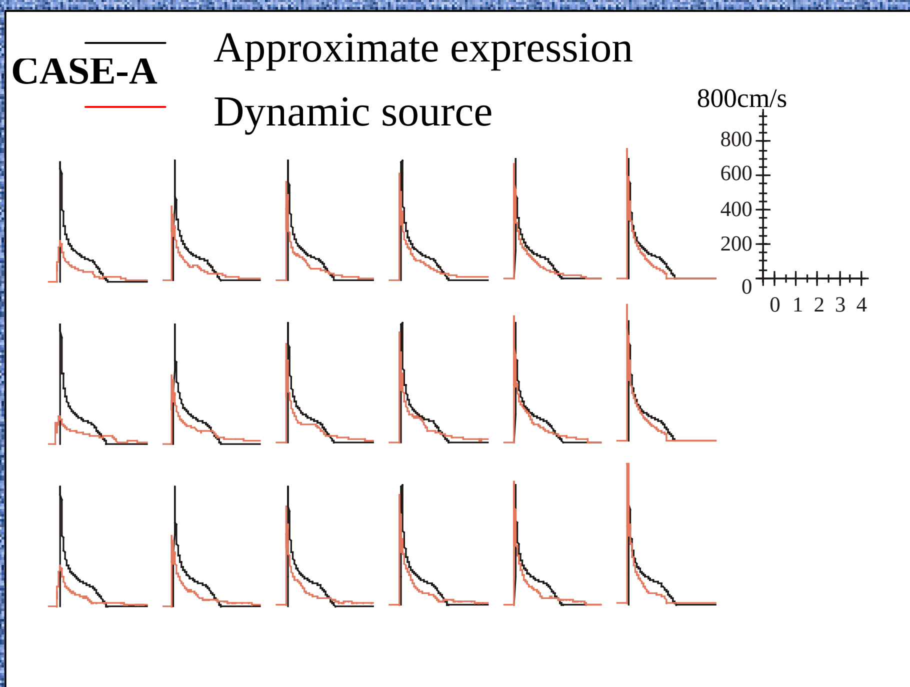
CASE-A



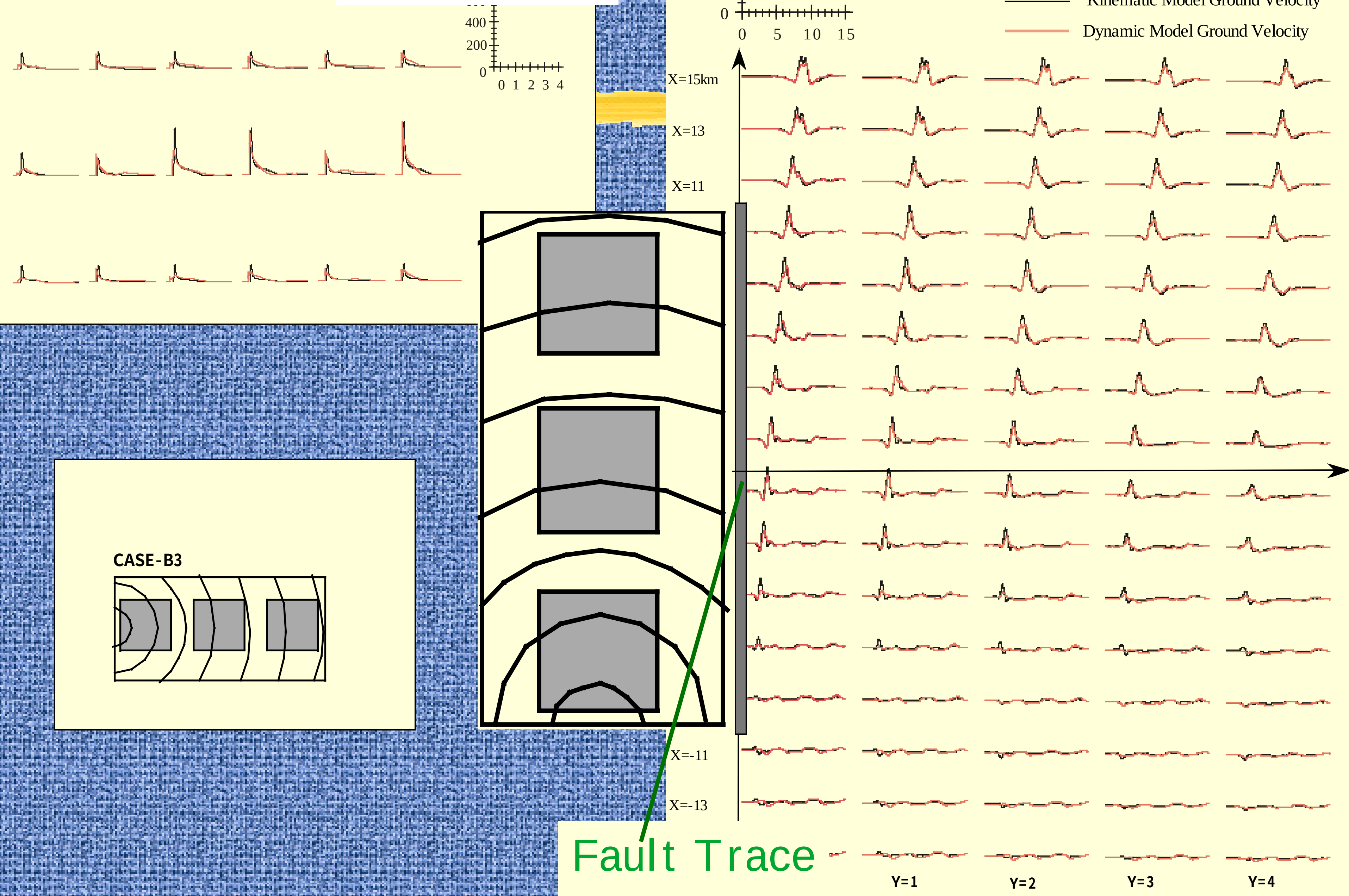
Fault normal ground velocity

Fault





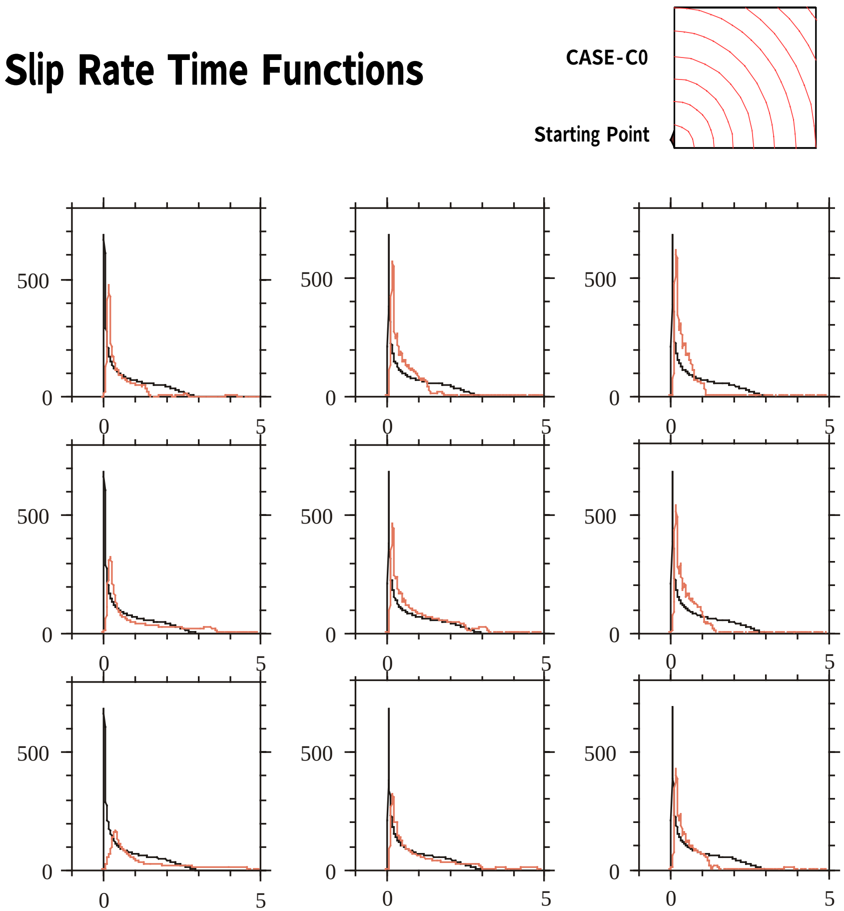
CASE-B3

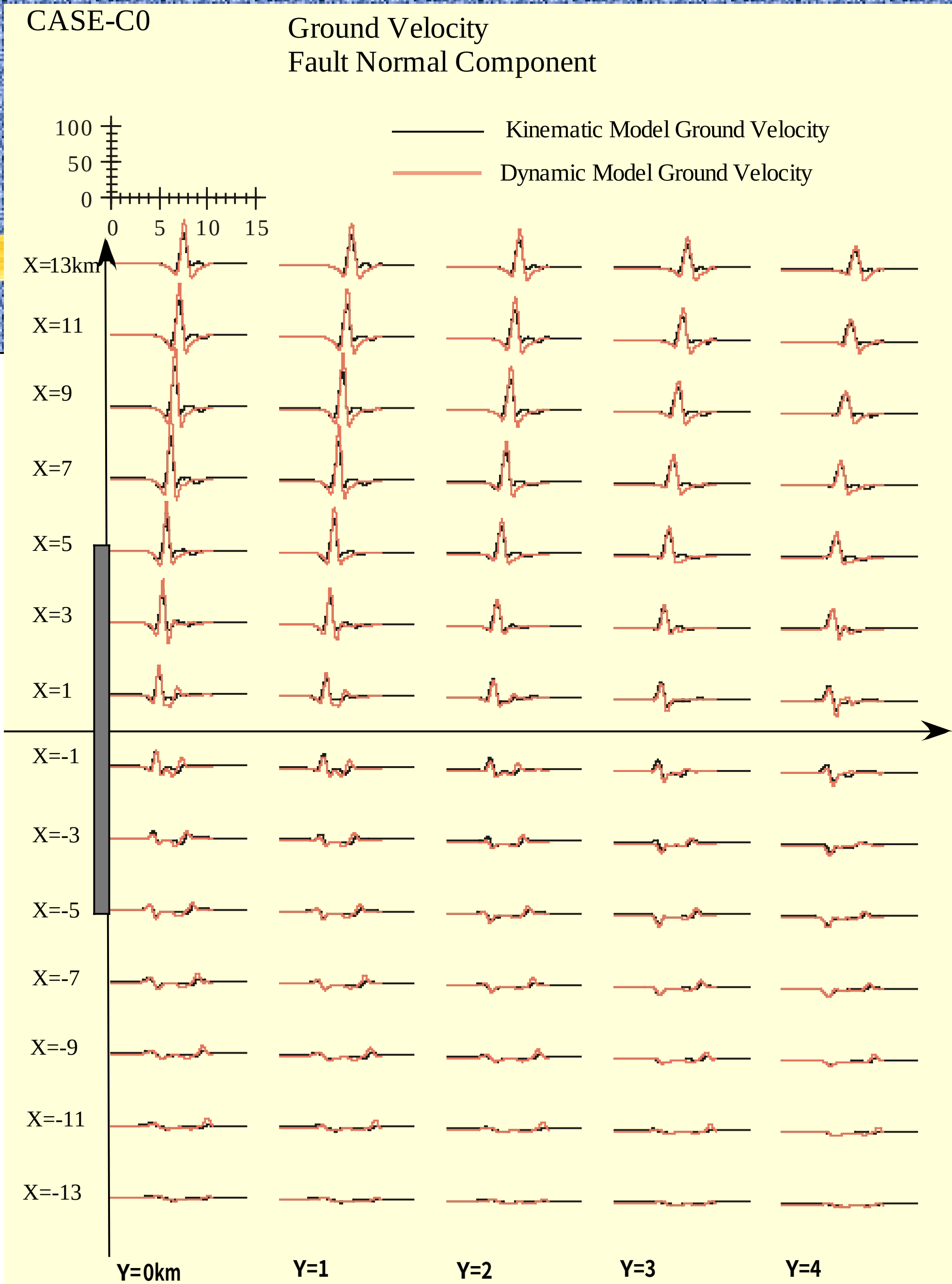


CASE-B3'
400
200
0
0 1 2 3 4
CASE-B3
Fault Normal
Kinematic Model Ground Velocity
Dynamic Model Ground Velocity
0
0 5 10 15
X=15km
X=13
X=11
X=-11
X=-13
Y=1
Y=2
Y=3
Y=4
Fault Trace

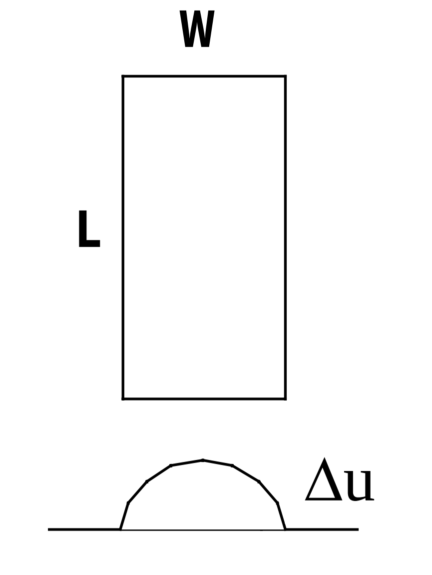
CASE-C

Slip Rate Time Functions





Slip distribution



Approximate expression of slip

$$\Delta u(x,y) \approx \frac{\Delta\sigma}{\mu}\frac{\sqrt{1+\left(\frac{L}{W}\right)^2}}{1+\frac{4}{3}\left(\frac{L}{W}\right)^2} W\sqrt{1-\left(\frac{2y}{W}\right)^2}\sqrt{(2-\eta)\eta}$$

$$\eta(x) = \begin{cases} |L-2x|/W & if\ |L-2x| < W \\ 1 & if\ |L-2x| \geq W \end{cases}$$

Chinerry(1960) and Day(1982)

Computer simulation of strong ground motion using dynamic faulting process

Peak Velocity

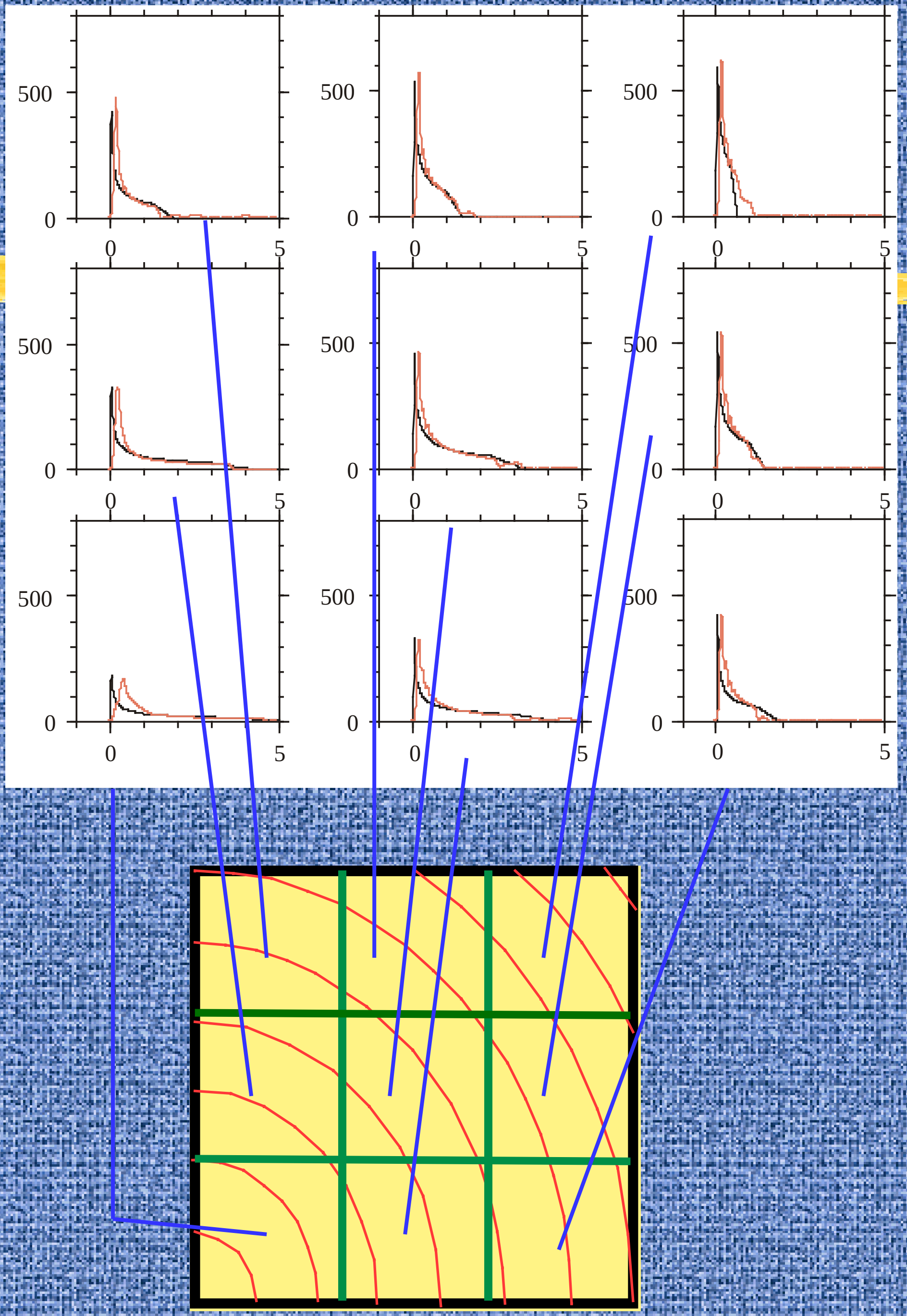
$$V_{\max} = C(v)\frac{\Delta\sigma}{\mu}\beta\sqrt{\frac{2rf_{cut}}{v}+1}$$

Rise time

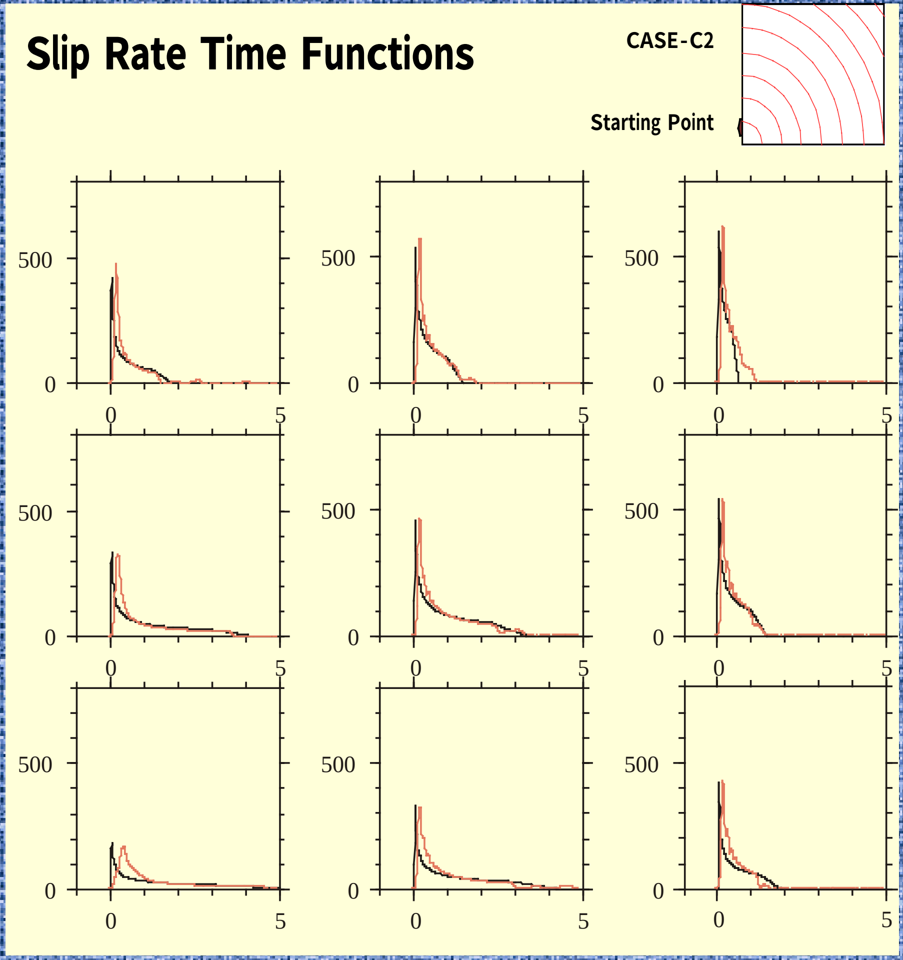
$$Tr(x,y) = \frac{w}{2v}\left[1-\left(\frac{2y}{w}\right)^2\right]\left[2-\xi(x)\right]\xi(x)$$

$$\xi(x) = \begin{cases} 2\dfrac{|L-x|}{w} & if\ |L-x| < w/2 \\ 1 & if\ |L-x| \geq w/2 \end{cases}$$

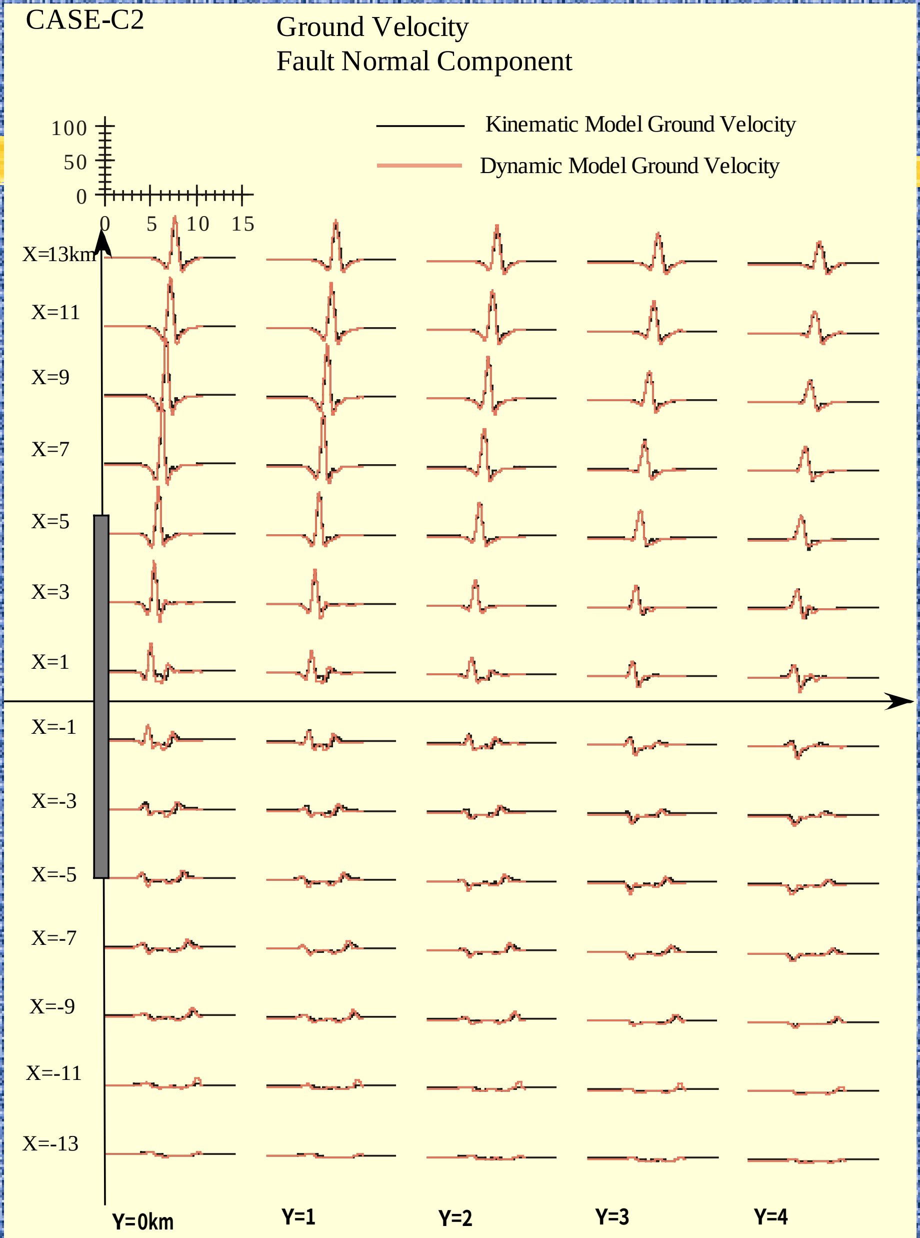
Day(1982)



CASE-C’



Slip Rate Time Functions
CASE-C2
Starting Point
500
0
0
5



CASE-C2
Ground Velocity
Fault Normal Component
Kinematic Model Ground Velocity
Dynamic Model Ground Velocity
100
50
0
0
5
10
15
X=13km
X=11
X=9
X=7
X=5
X=3
X=1
X=-1
X=-3
X=-5
X=-7
X=-9
X=-11
X=-13
Y=0km
Y=1
Y=2
Y=3
Y=4

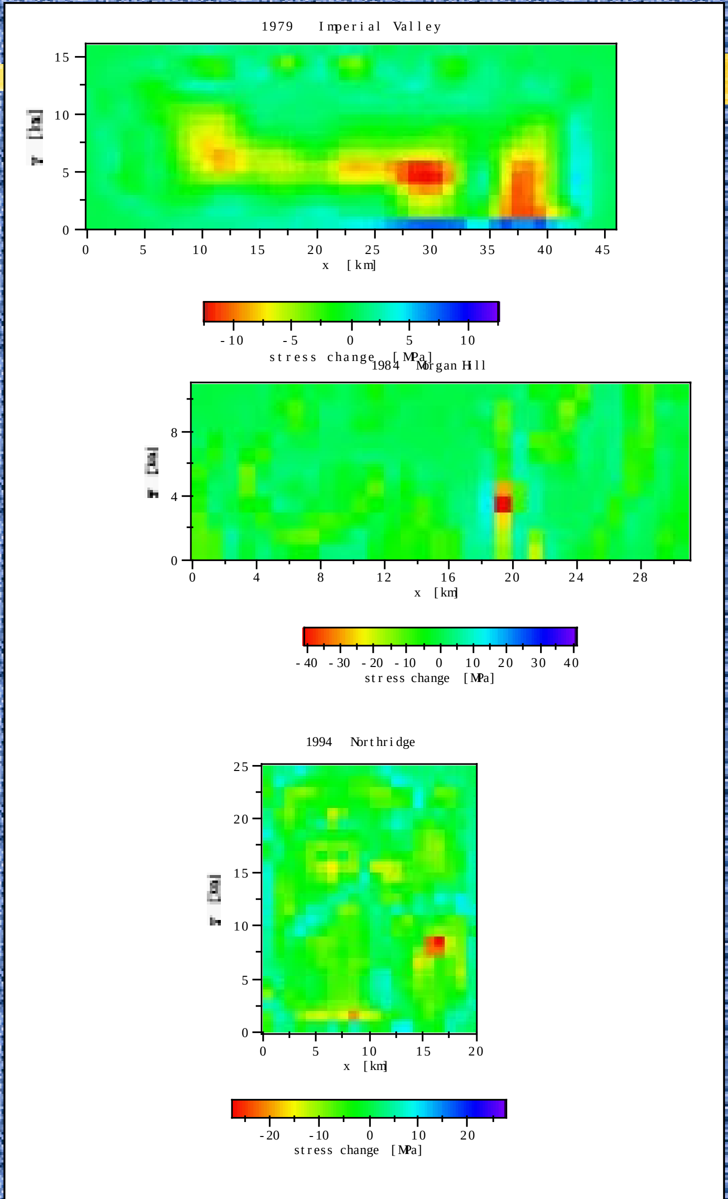
結論

- 動力学モデルの数値シミュレーションに基づく滑り速度時間関数の作成
- 滑り速度時間関数の近似式による断層近傍の地震波形
- 動的モデルによる地震波形と一致

今後

- 具体例を通して精密化
- （もっともっと不均質な場合への適用）
- 短周期
  - Slip rate time functionよりも破壊過程が効く

応力降下量分布


1979 Imperial Valley
x [km]
stress change [MPa]
1984 Morgan Hill
x [km]
stress change [MPa]
1994 Northridge
x [km]
stress change [MPa]