Finite Earthquake Source Modeling

based on 1-point and 2-point statistics of kinematic source parameters

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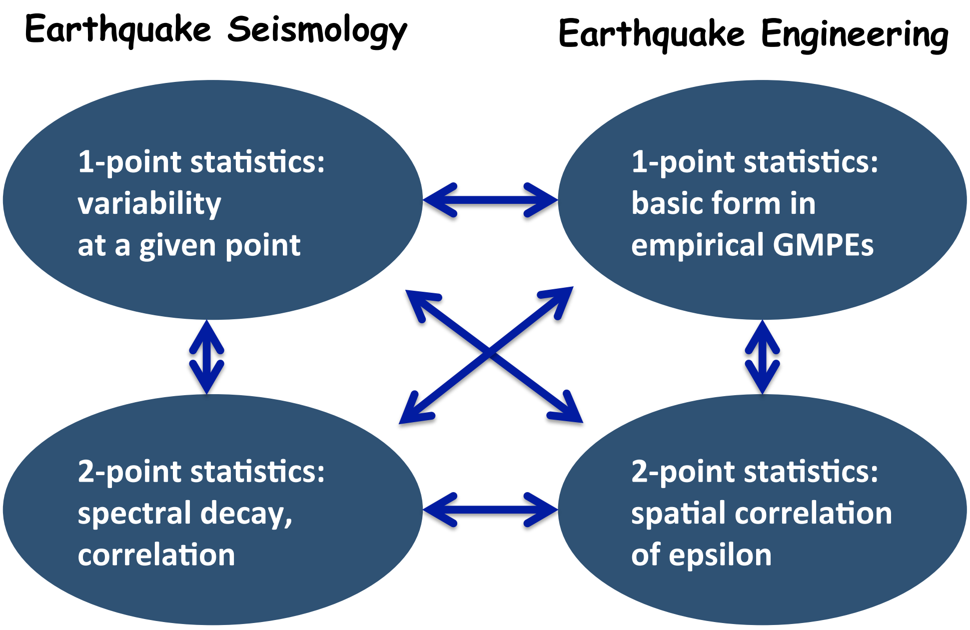
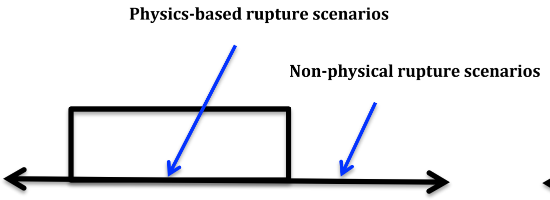
Consistency !!

in ground motion modeling



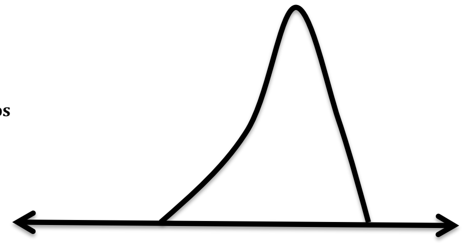
Quantifying the likelihood of rupture scenarios

(a)



a) Non-zero, but **uniform probability** is assigned to physics-based (physically-acceptable) rupture scenarios. Zero probability is assigned to non-physical rupture scenarios

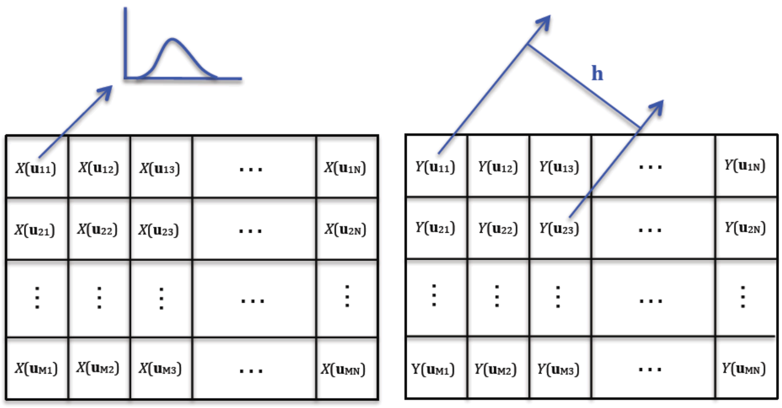
(b)



b) **Non-uniform probability** distribution within the physics-based rupture scenarios

Physics-based (pseudo-dynamic) rupture modeling may help us to exclude non-physical rupture scenarios, but the next step is to quantify the likelihood of the physically admissible rupture scenarios

Finite source modeling
with spatial random field models



Continuous random field

$$\{X(\mathbf{u}), \forall \mathbf{u} \in A\}$$

Discrete random field

$$\{X(\mathbf{u}_{ij}), i = 1,\ldots,M, j = 1,\ldots,N\}$$

Autocorrelation

$$Cov\left(X(\mathbf{u}_{ij}), X(\mathbf{u}_{ij}+\mathbf{h})\right) = Cov\left(X(\mathbf{u}_{pq}), X(\mathbf{u}_{pq}+\mathbf{h})\right) = Cov_{XX}(\mathbf{h}), \quad \rho_{XX}(\mathbf{h}) = Cov_{XX}(\mathbf{h}) / \sigma_X^2$$

Cross-correlation

$$Cov\left(X(\mathbf{u}_{ij}), Y(\mathbf{u}_{ij}+\mathbf{h})\right) = Cov\left(X(\mathbf{u}_{pq}), Y(\mathbf{u}_{pq}+\mathbf{h})\right) = Cov_{XY}(\mathbf{h}), \quad \rho_{XY}(\mathbf{h}) = Cov_{XY}(\mathbf{h}) / \sigma_X\sigma_Y$$

Spatial correlation (2-point stats.)

Auto and cross-covariance function and correlogram

$$C(\boldsymbol{h}) = E\{(X(\boldsymbol{u}) - m_X)(\underline{Y(\boldsymbol{u}+\boldsymbol{h})} - m_Y)\}$$

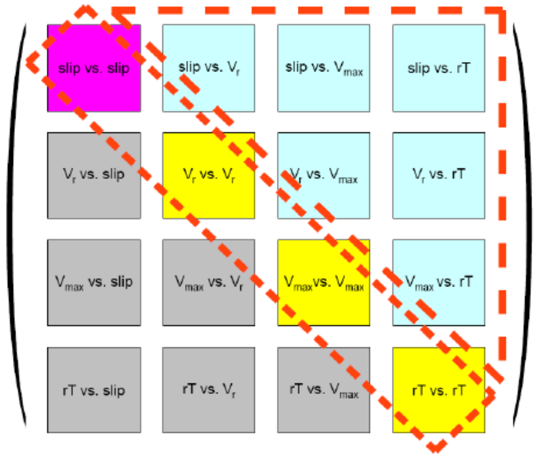
$$\rho(\boldsymbol{h}) = C(\boldsymbol{h})/(\sigma_X \sigma_Y)$$

$$\hat{C}(\boldsymbol{h}) = \frac{1}{N(\boldsymbol{h})}\sum_{\alpha=1}^{N(\boldsymbol{h})} x(\boldsymbol{u}_\alpha) \cdot y(\boldsymbol{u}_\alpha + \boldsymbol{h}) - \hat{m}_X \hat{m}_Y$$

$$\hat{m}_X = \frac{1}{N(\boldsymbol{h})}\sum_{\alpha=1}^{N(\boldsymbol{h})} x(\boldsymbol{u}_\alpha)$$

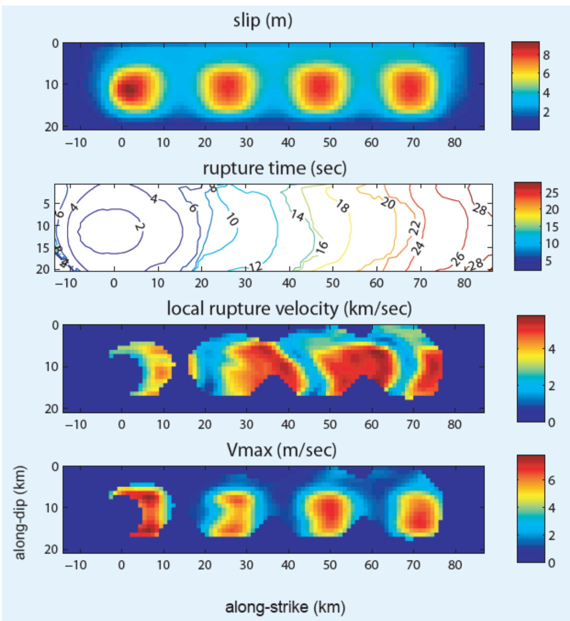
$$\hat{\sigma}_X^2 = \frac{1}{N(\boldsymbol{h})}\sum_{\alpha=1}^{N(\boldsymbol{h})} (x(\boldsymbol{u}_\alpha) - \hat{m}_X)^2$$

$\Sigma =$



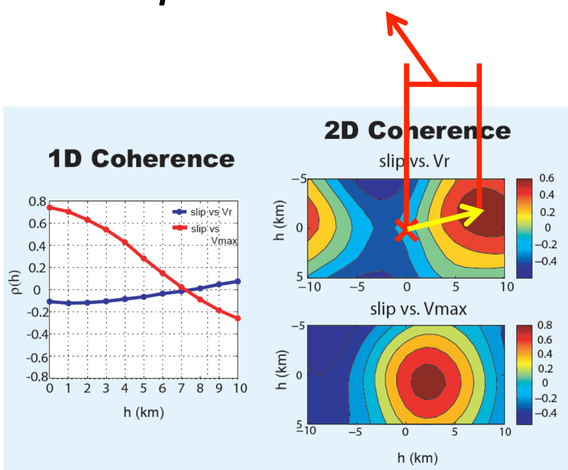
Spatial correlation

from dynamic rupture models



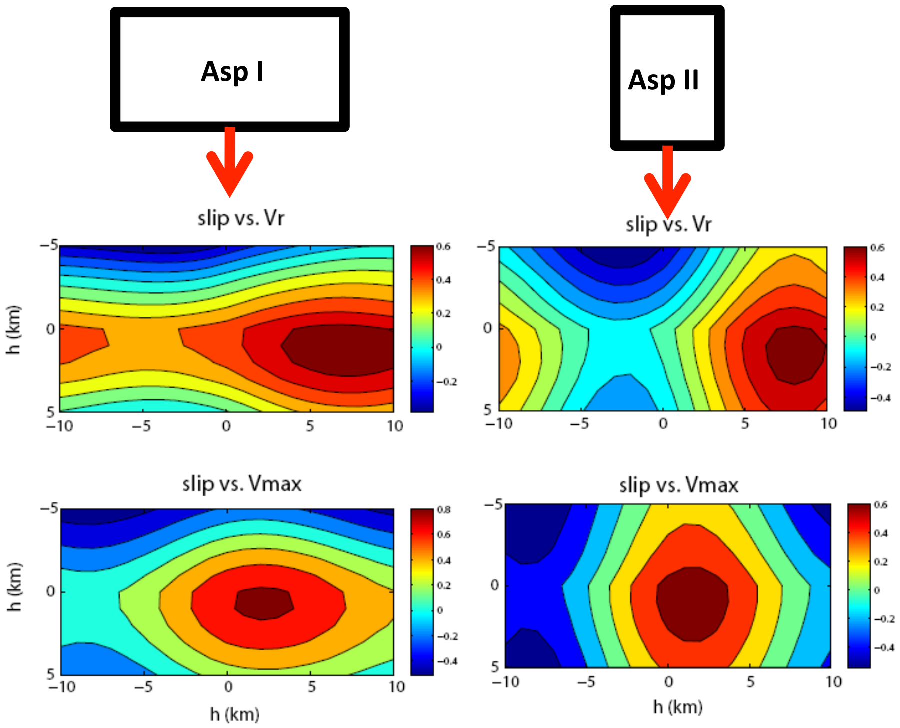
(Dalguer et al., 2008)

Response Distance **~ 8 km**



(Song and Somerville, 2010)

Does asperity shape affect correlation?

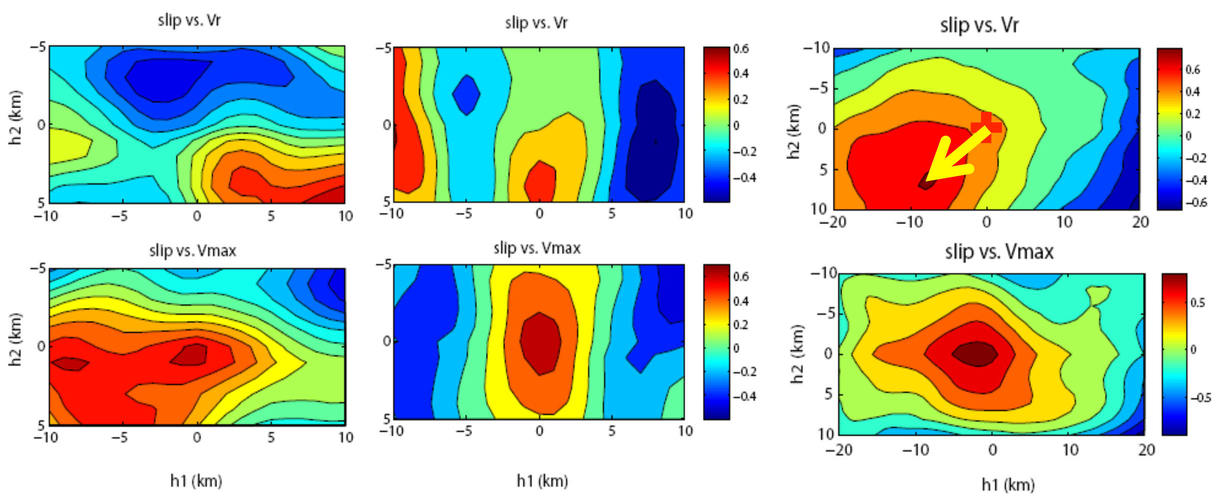


Spatial correlation

in the 1992 M_w 7.2 Landers, California, event

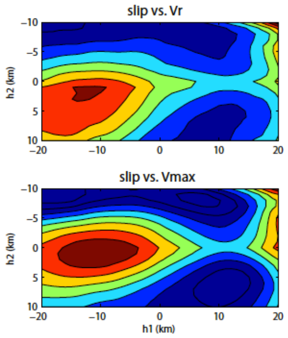
Kinematic | *Dynamic*

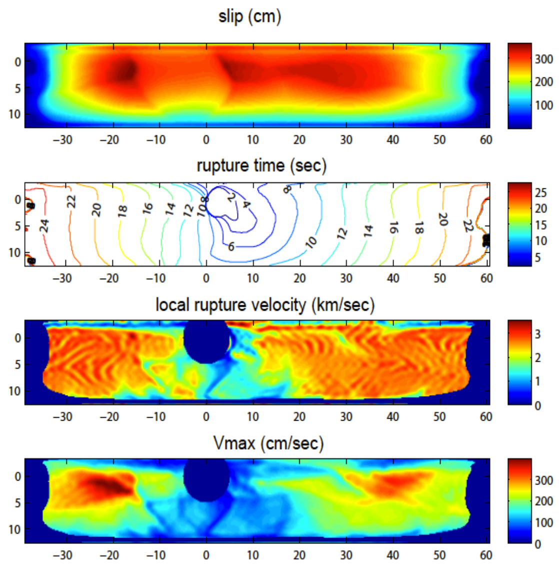
Hernandez et al. (1999) | Wald and Heaton (1994) | Peyrat et al. (2001)



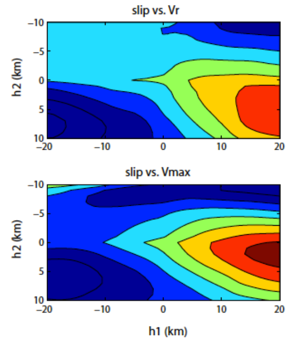
Non-stationarity
in spatial correlation

rupture to the left





rupture to the right



Bi-lateral rupture

Earthquake Source Statistics
to quantify the variability of rupture processes

- **1-Point Statistics**

- Scaling of mean slip and sigma with earthquake size

- Supershear and subshear

- Crack-like and pulse-like rupture

- Stick-slip and creeping

- **2-Point statistics**

- *Auto-coherence*: define heterogeneity of source parameters

- *Cross-coherence*: control coupling between different parameters