Near-fault large-event ground motion models

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Ground motion models

"Ground motion prediction equations"

Objective: predict high-frequency acceleration and Peak Ground Acceleration (PGA)

Random Vibration Theory

Hanks and McGuire (1981)

Many sources patches on fault plane generate random high-frequency signal that a component of the station sums.

For large earthquake, signal is transiently stationary and Gaussian.

R.M.S. acceleration is

$a_{\mathrm{rms}} = C_H\,(\Delta\tau / \rho R)\ \mathrm{sqrt}(f_{\max}/ f_0)$

C_H is a dimensionless multiplicative constant, $\Delta\tau$ is the stress drop, ρ is density, and R is distance

Spectrum is flat from corner frequency f_0 to the upper limit of the band $f_{\max}$.

Fault dimension is $r = \beta/f_0$

Modify equation for near-fault station and large earthquake

Solid angle is dimensionally, $B = (\beta/ f_0 R)^2$

Near-fault R.M.S. acceleration is

$a_{\mathrm{rms}} = C_H\,(\Delta\tau / \rho\beta)\ \ B^{1/2}\ \mathrm{sqrt}(f_{\max}\,f_0)$

$= C_H\,V_{\mathrm{slip}}\,B^{1/2}\ \mathrm{sqrt}(f_{\max}\,f_0)$

$(\Delta\tau / \rho\beta)$ is slip velocity V_{slip}

$\mathrm{sqrt}(f_{\max}\,f_0)$ is characteristic frequency

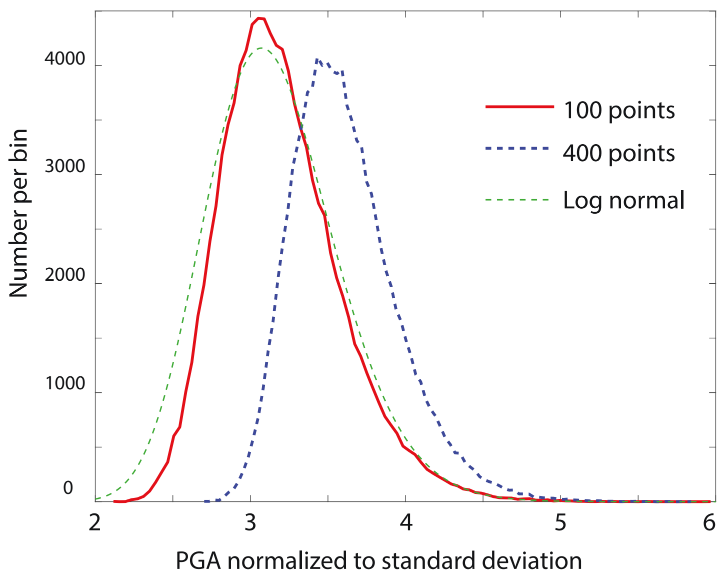
When major fault slips near the station, the solid angle subtended by slipping fault may approach ~π steradians (quarter space for strike-slip fault).

Solid angle $B^{1/2}$ modulates quasistationary Gaussian signal.

PGA is extremal for acceleration. Monte Carlo calculation.

Nonstandard PGA is resolved horizontal velocity.

This parameter has predicted circular Gaussian distribution for random additive sources.

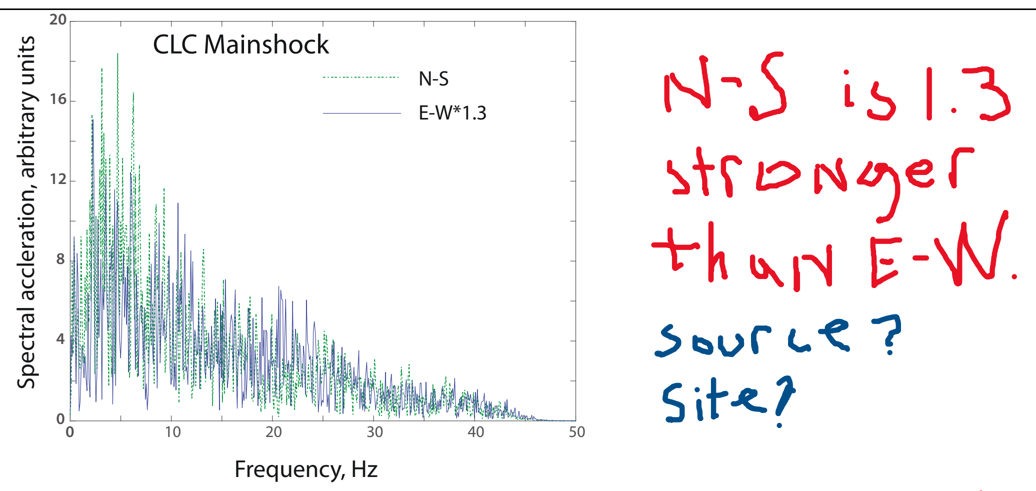


Tail of distribution of PGA from random sums is approximately lognormal. Logarithmic standard deviation is 0.132. Observed is 0.44 and 0.58 for M_w>7 (Gregor et al., 2014).

Likely causes of observed scatter in near-fault PGA.

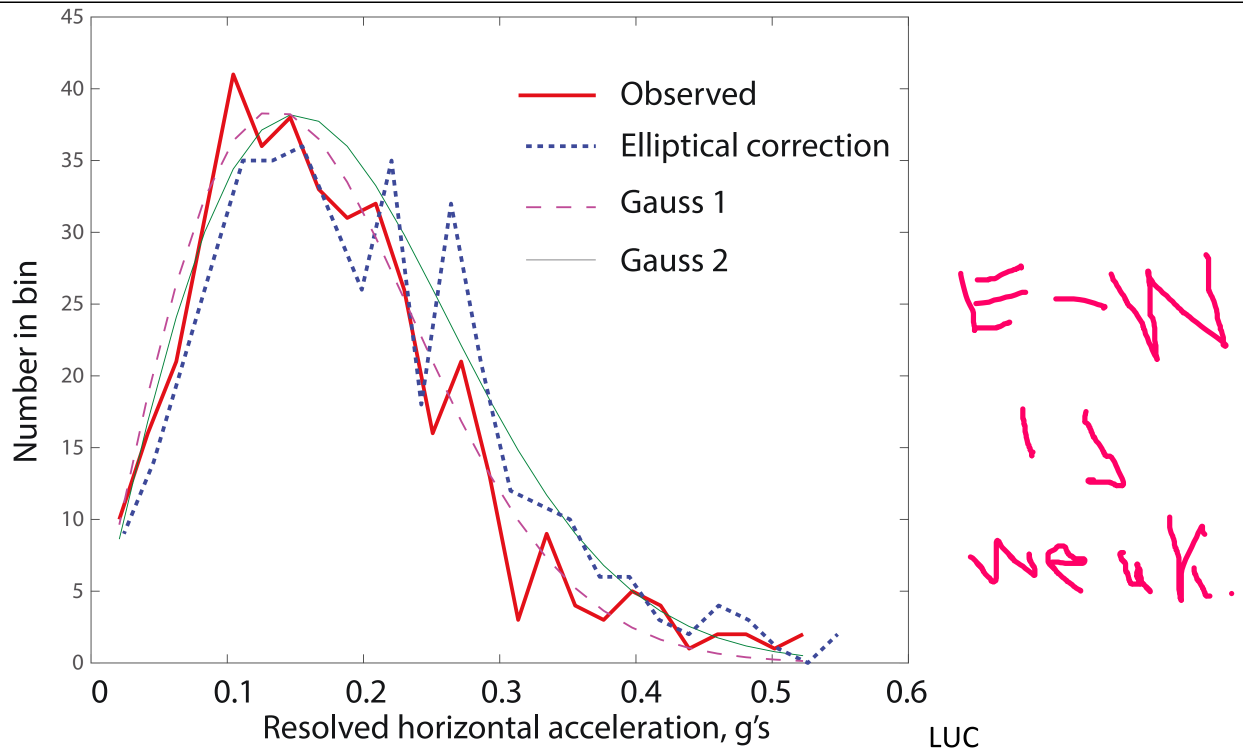
1. Solid angle is rarely ~π: Bounded multiplicative factor.
   - V_{slip} Multiplicative, fault patch
   - $\mathrm{sqrt}(f_{max}\,f_0)$ Multiplicative, fault patch + path

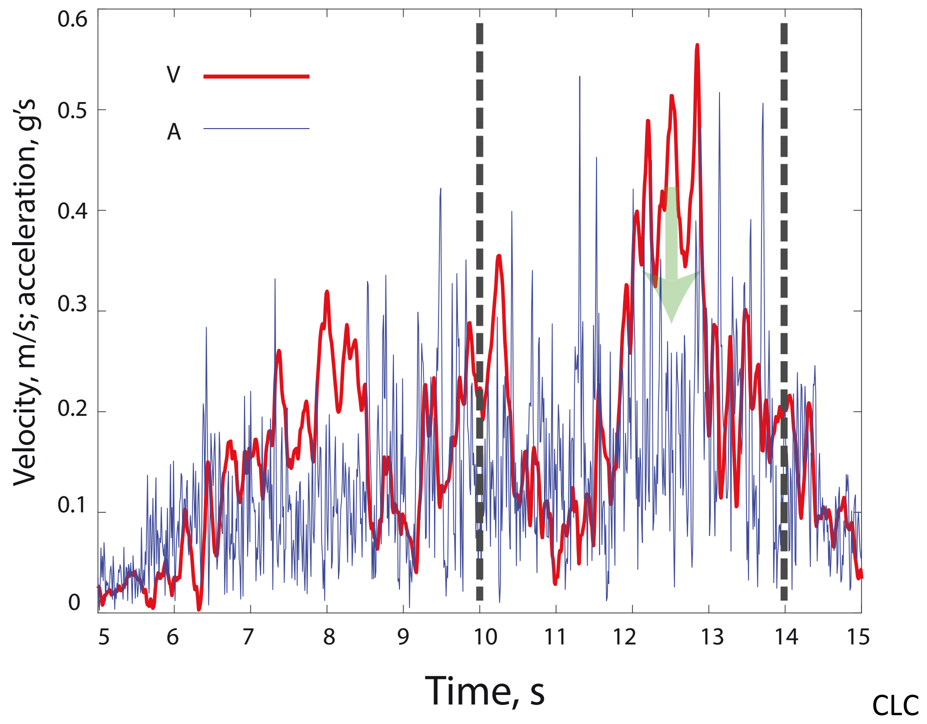
   Multiplicative -> lognormal
2. Rogue strong subevents cause spikes: Not modeled by Gaussian distribution. Events are locatable.

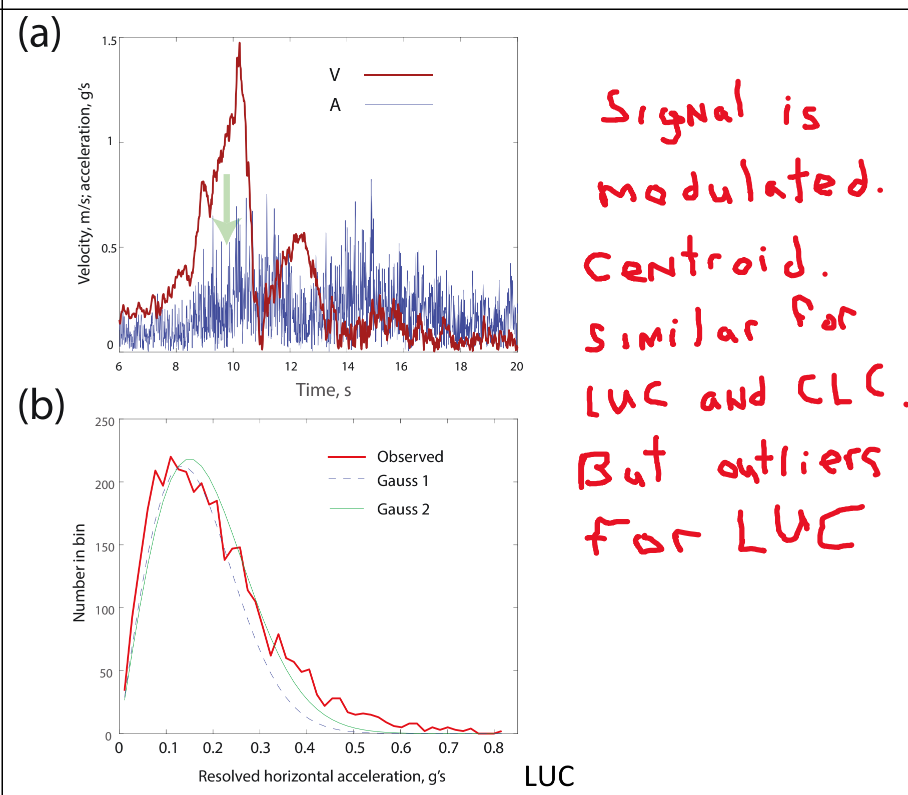


Frequency is not flat for near-fault station. Path lengths and attenuation differ.

PGA as outlier. Only two available events. CLC Ridgecrest; LUC Landers.







Circular Gaussian distributions crudely fit resolved acceleration histograms for CLC and LUC. But there are outliers. Pooling modulated signal underestimates standard deviation at times of high amplitude. PGA tends to occur at times of high overall amplitude. Empirical modulation function may be projected to fault or compared with fault-slip models.