GMPE for Instantaneous Power(IP) for Near-Fault Ground Motions

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Primary and Secondary Ground-Motion Parameters

- Primary Ground-Motion Parameters
  - Horizontal PSA(T) at 5% damping
- Examples of Secondary Ground-Motion Parameters
  - Arias intensity
  - Peak ground velocity
  - CAV
  - Vertical PSA(T)
  - PSA(T) at other damping values
  - Chance of a velocity pulse

Estimating Secondary Ground-Motion Parameters

- Traditional GMM Approach – full hazard
  - Develop a new GMM (scaling with M,R,VS30 …) for the new parameter
  - Rerun hazard for new GM parameter
  - Issue that the hazard at a given return period for the primary and secondary GM parameters may be controlled by different eqk
- Traditional GMM Approach - Application to design ground motions
  - Develop a new GMM (scaling with M,R,VS30 …) for the new parameter
  - Determine the scenario (M,R, …) from the deaggregation of hazard for the primary GM parameter (i.e. horizontal PSA(T_0))
  - Compute median and sigma of new GM parameter
  - This give consistent scenarios, but may not be consistent in the ground motions

Estimating Secondary Ground-Motion Parameters

- Conditional GM Approach
  - Develop a new GMM that includes the PSA(T_0) as an input parameter to the model
    - Use primary measures of the ground motion to better constrain the secondary GM parameters
  - Key is that the design PSA(T) may not be the median
    - If above average PSA(T), the likely above average secondary parameters as well
  - Leads to an estimate of the secondary GM parameter that is consistent with the design spectrum

Developing Conditional Ground-Motion Models

Common approach normalizes by the horizontal PSA(T)

$$ln\left(\frac{IM}{PSA(T)}\right) = c_1 + c_3 M$$

More General Form includes horizontal PSA as a parameter in the regression:

$$\ln(IM) = c_1 + c_3 M + c_2 ln(PSA(T))$$

The c_2 coefficient is related the difference in variability of PSA(T) and the secondary parameter (PGV). In general, it is not unity.

Examples of Conditional GMMs Using Normalized IMs

- V/H ratios

$$ln\left(\frac{PSA_V(T)}{PSA_H(T)}\right) = f(M, R, VS_{30})$$

- Damping Scale Factors

$$ln\left(\frac{PSA_{10\%}(T)}{PSA_{5\%}(T)}\right) = f(M, R, \ldots)$$

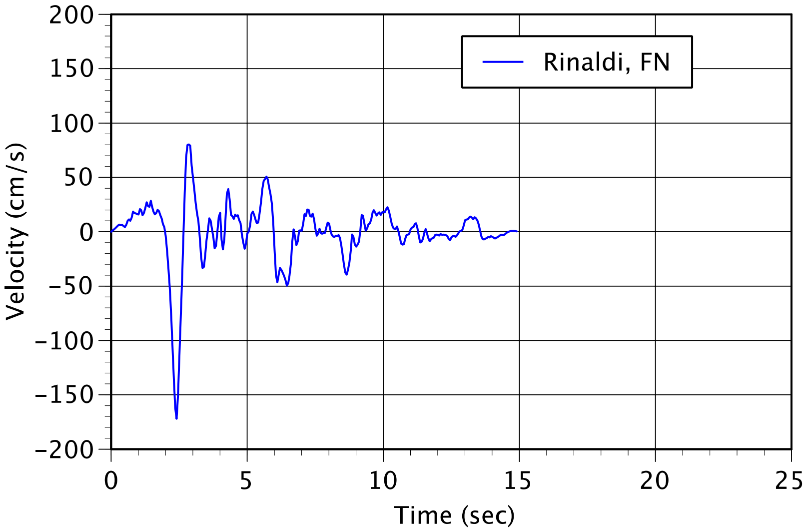
Limitation of the Normalization Approach for Conditional GMM

- In the general form
  - $c_2 = \rho(\ln(IM), \ln(PSA(T))) \frac{\sigma_{lnIM}}{\sigma_{lnPSA}}$
  - ρ is the correlation between the residuals from the IM and PSA(T). Similar to the correlation used for the CMS
- Using the normalized form assumes that c_2=1
  - This happens if
    - ρ=1 and $\sigma_{lnIM} = \sigma_{lnPSA}$
    - or more generally $\rho(\ln(IM), \ln(PSA(T))) = \frac{\sigma_{lnPSA}}{\sigma_{lnIM}}$

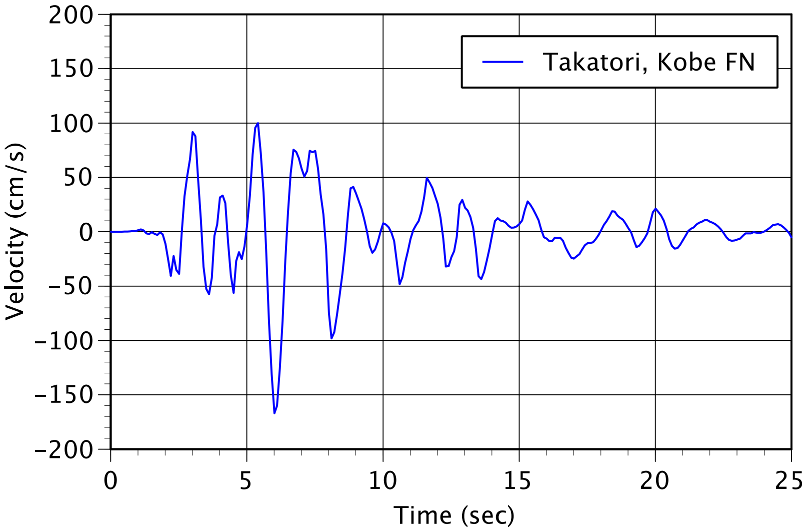
Examples of Large Near-Fault Velocities

Are These Both Pulses?

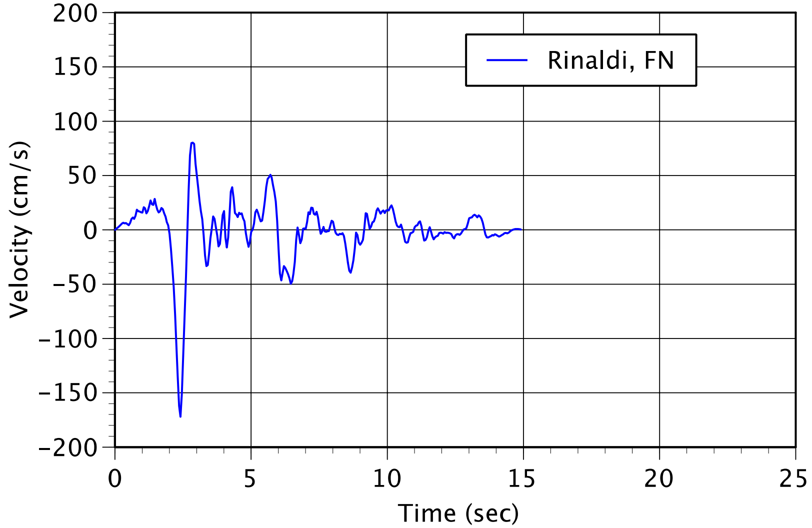
1994 Northridge

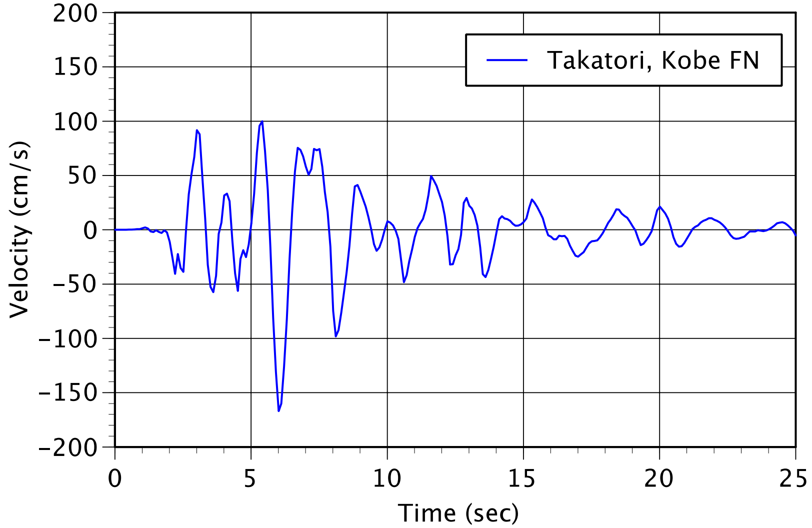


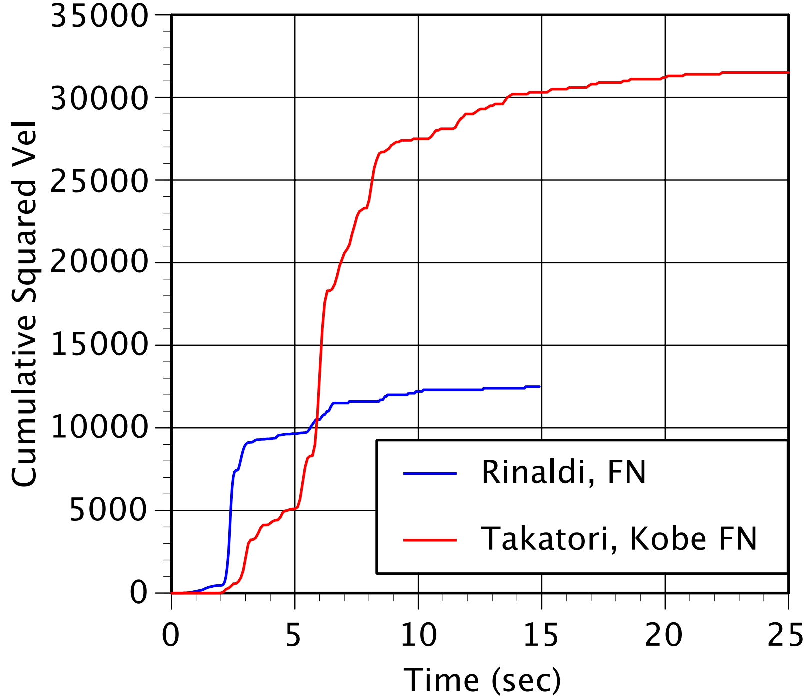
1995 Kobe



Slope of the Cumulative Squared Velocity





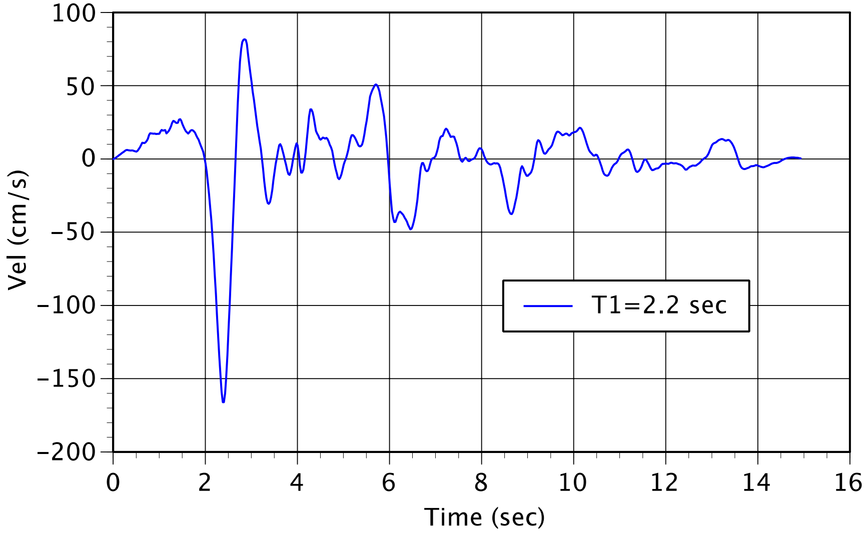


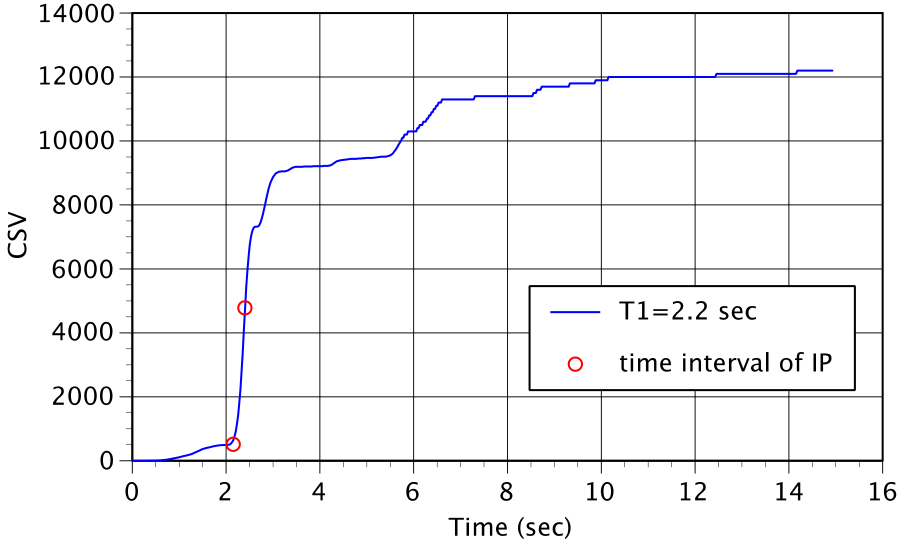
Instantaneous Power (IP)

- Band-pass filter the velocity time history
  - 0.2 T_1 to 3 T_1
- IP = Slope of the CSV at the time near the peak velocity
  - CSV = energy
  - Energy / time = power

From Zengin and Abrahamson (2019)

Example of IP



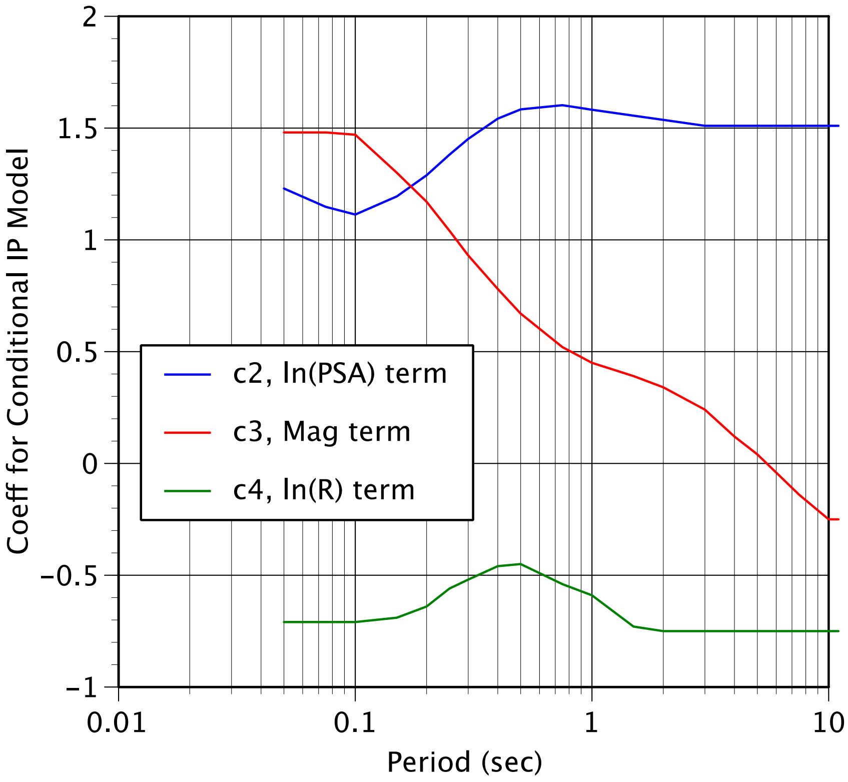


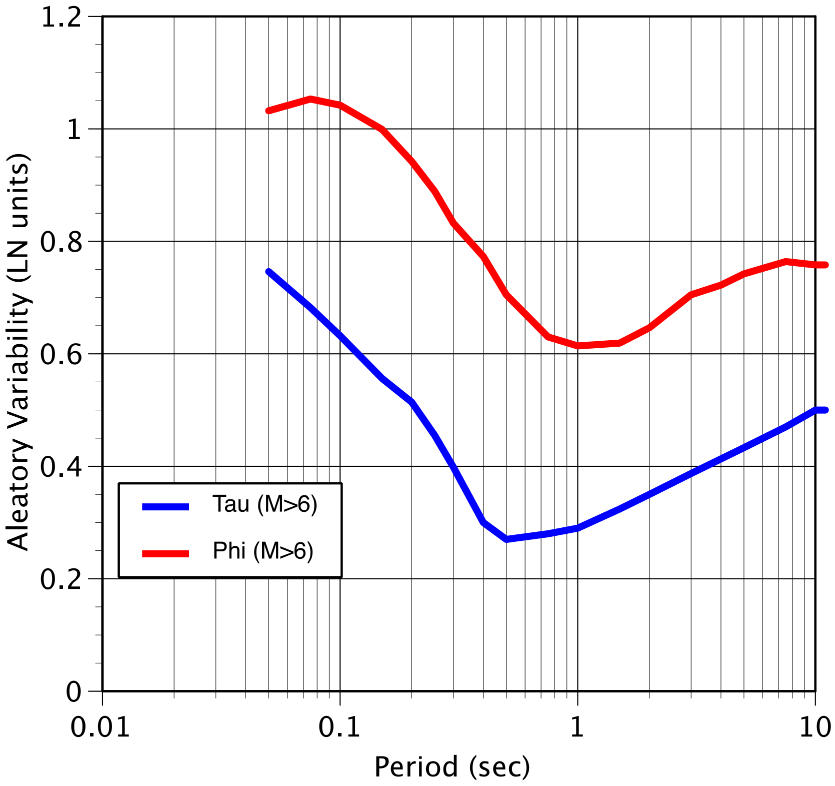
Conditional GMM for IP

- $Ln(IP(T_0)) = c_1 + c_2 ln(PSA(T_0)) + c_3 (M-6) + c_4 ln(R+5exp(M-6))$

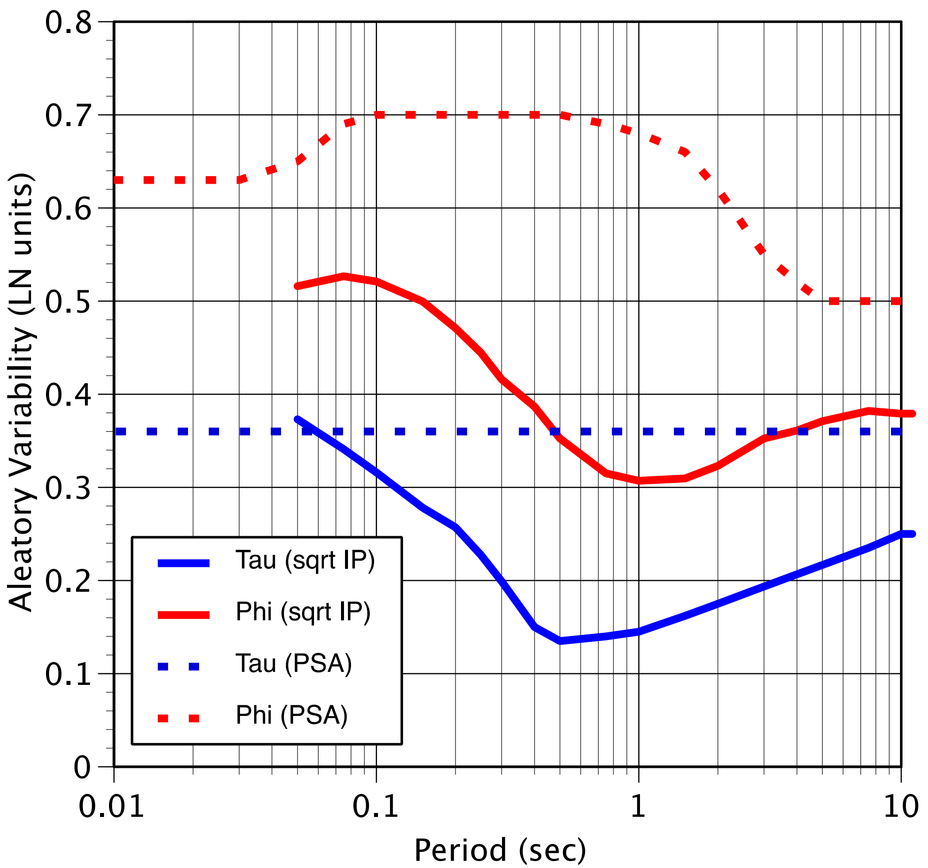
- Run the regression for different values of T_0.
  - Recall, velocity time series is bandpass filtered with the pass band depending on T_0.
  - Estimate coefficients for each T_0.

Coefficients for Conditional IP Model



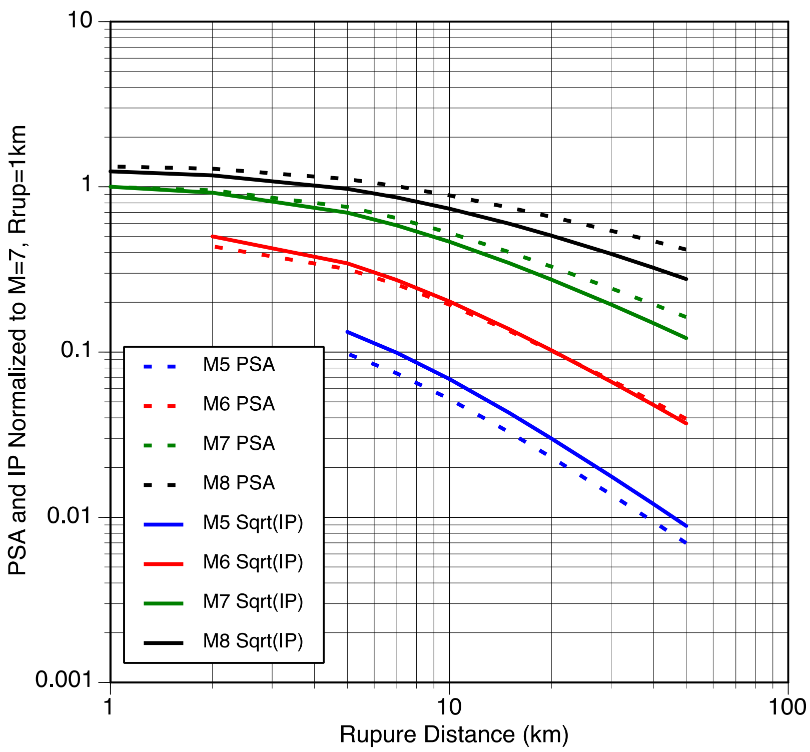


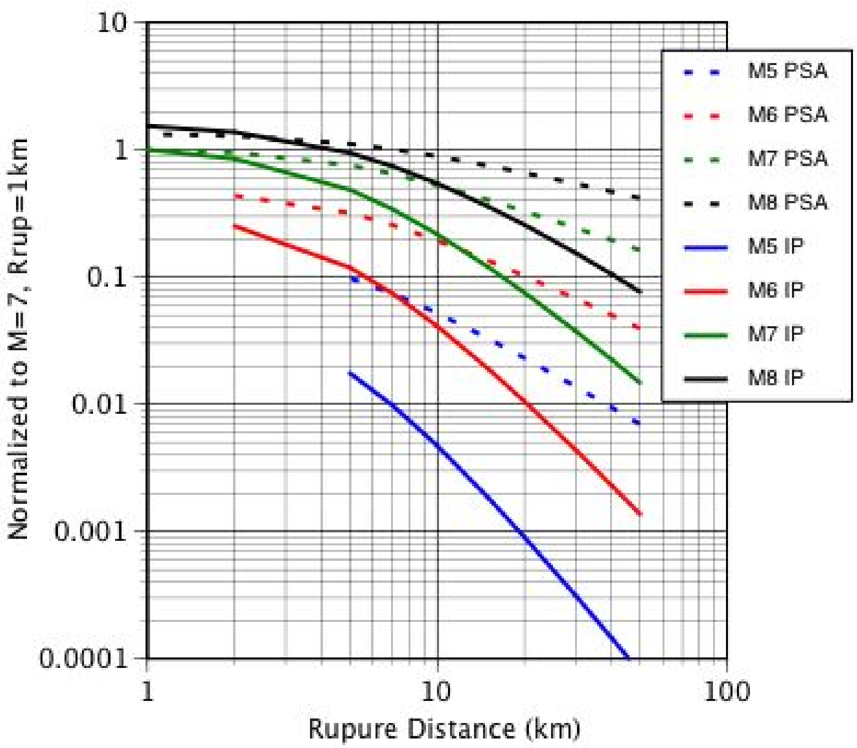
PSA and Sqrt(IP) Standard Deviations



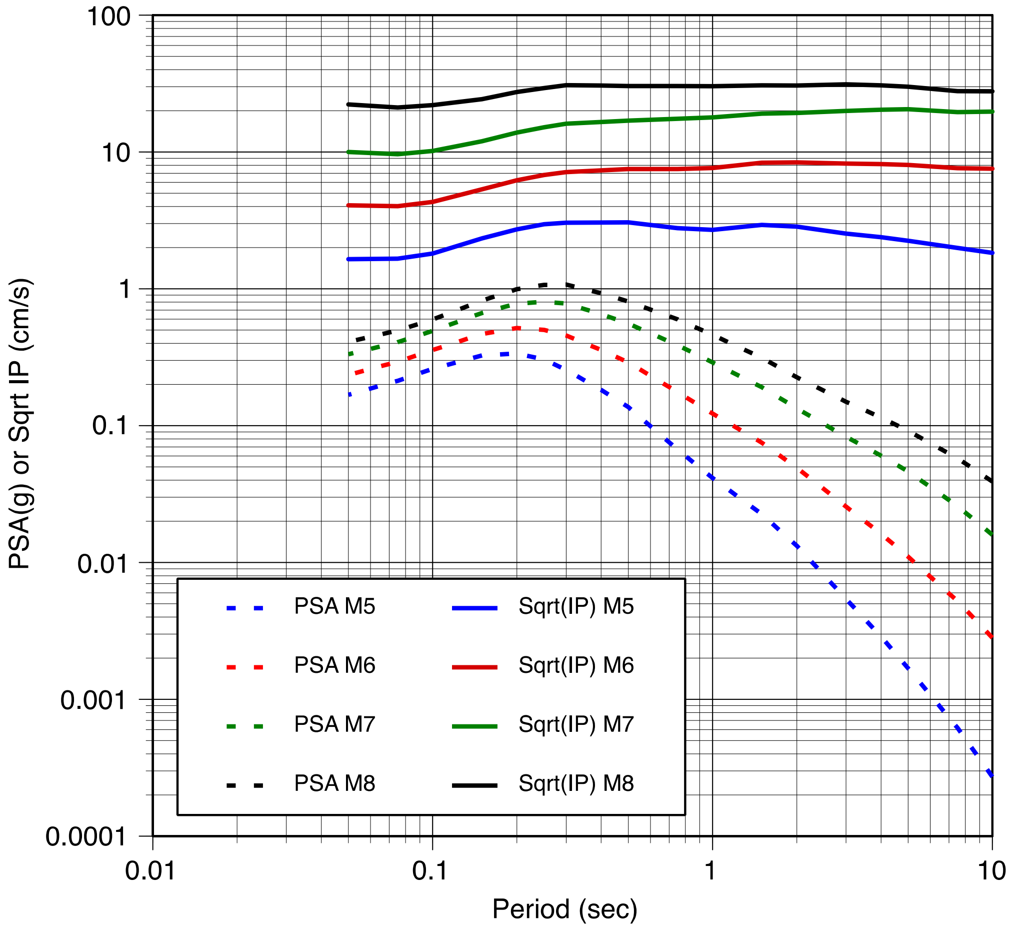
- Reduced standard deviation terms for Sqrt(IP) due to use of the conditional GMPE
  - Knowing PSA(T) reduces the variability of Sqrt(IP)

Comparison of PSA and IP scaling T=2 sec



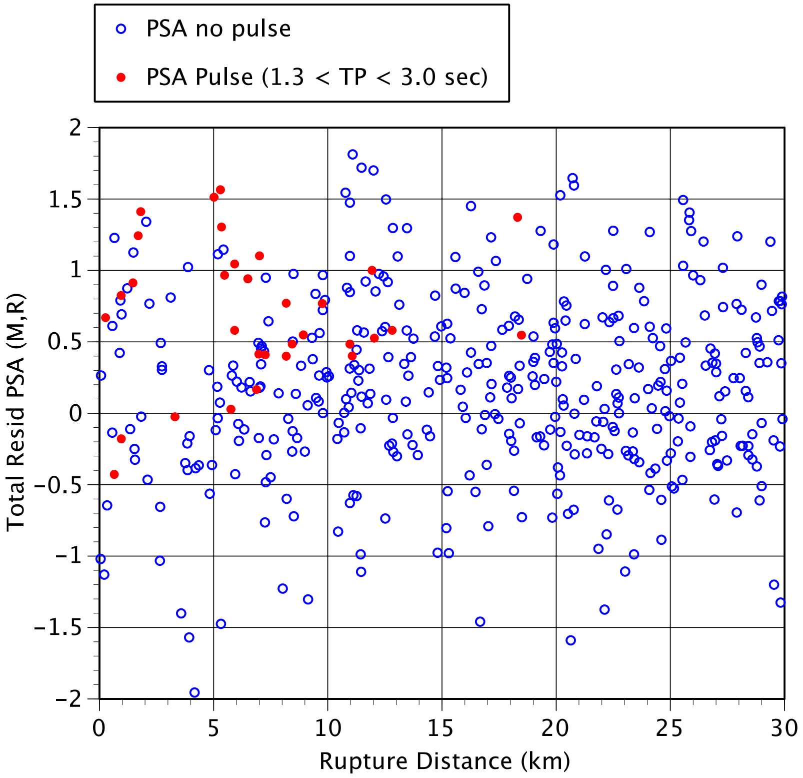


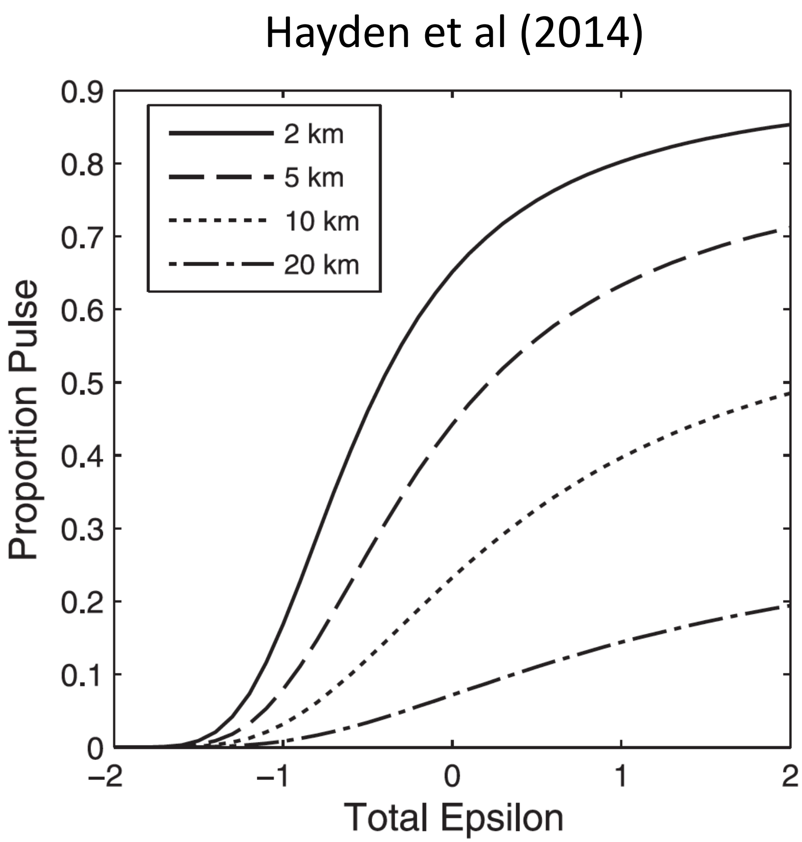
Comparison of Period Dependence of PSA and IP



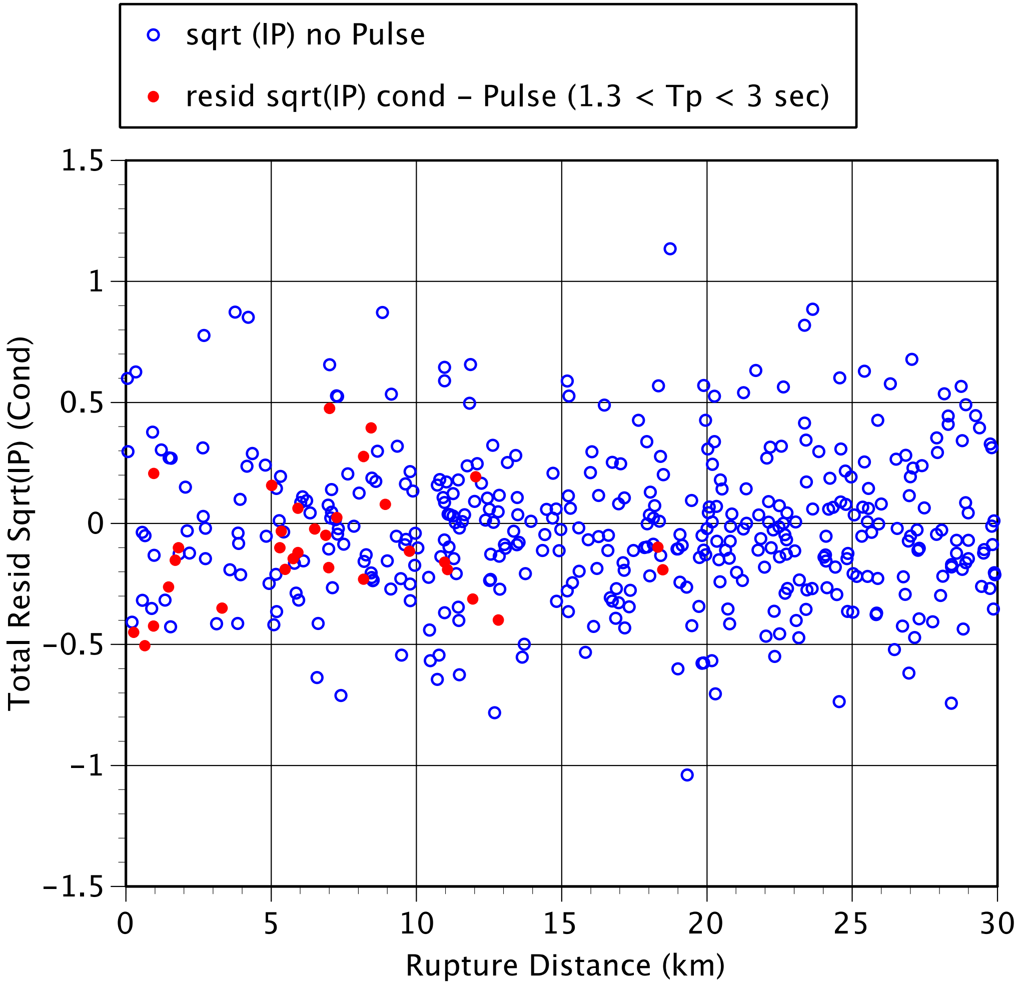
Example: PSA Residuals for T=2 sec

ASK14 data, M>=6.5, Rrup<30 km





Conditional GMPE removes the effect of the larger PSA from residuals



After accounting for the larger PSA, pulse records do not have an above average IP

Summary

- For near-fault ground motions consider replacing the velocity pulse with parameter that is better correlated with the nonlinear structural response
  - IP is one option
  - Consider other parameters based on high amplitudes for short durations