Parametric investigation of rigid blocks subjected to synthetic near-source ground motions

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introduction

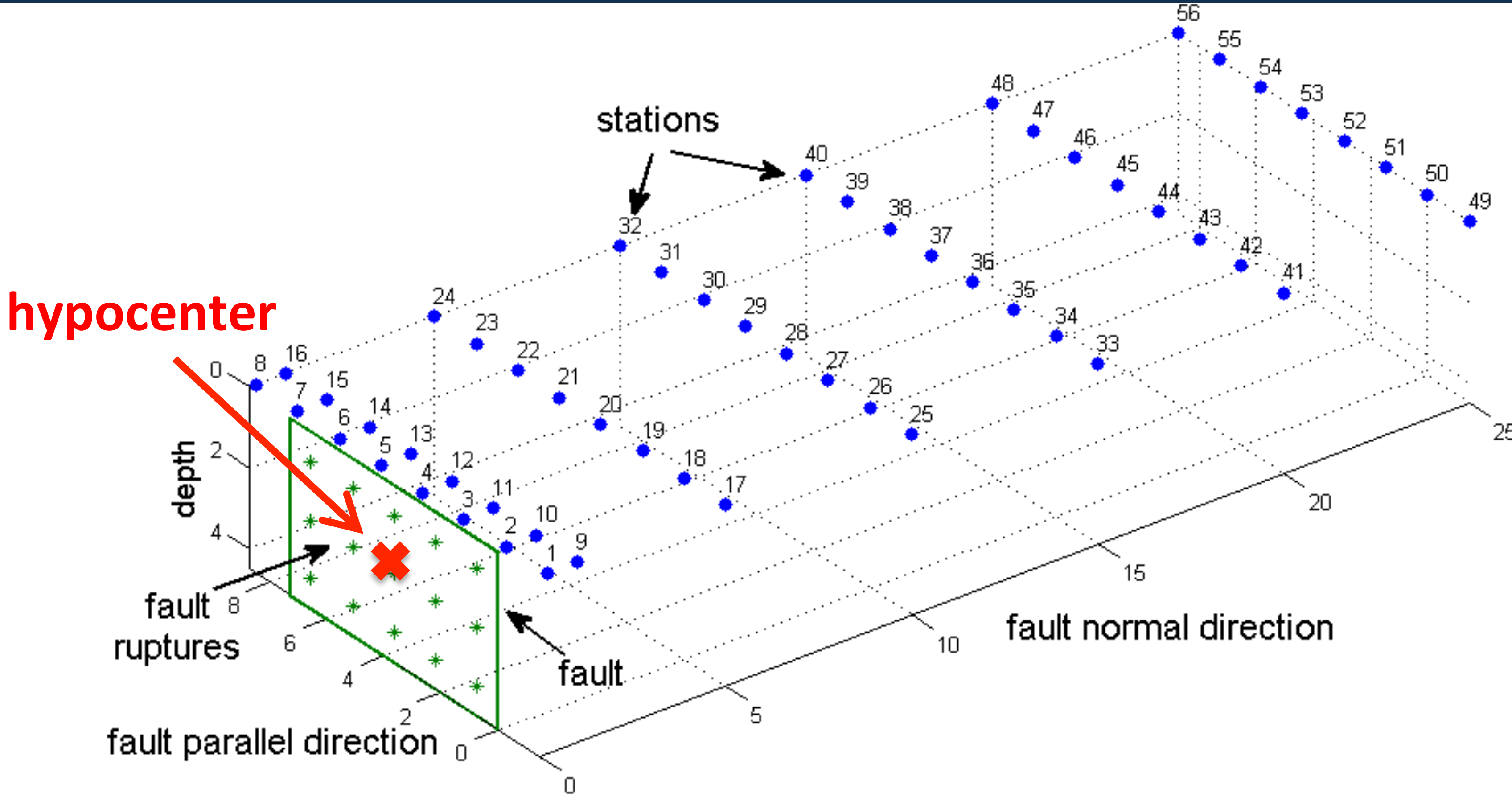
we perform **a systematic investigation** of the seismic response of rigid blocks subjected to near-source records of different magnitudes

generate **synthetic pulse-like** ground-motions consisting of a **low and high frequency** component for a dip-slip fault

consider several rigid block structures of **different geometry**

parametric investigation that **improves our understanding** on the effect of base motion characteristics on the **overturning** rigid block structures

synthetic ground motions



- assume a vertical fault and a grid of 56 receiver stations
- consider events with M_w =5.5, 6.0, 6.5, 7.0 and 7.5 - the fault size varies accordingly
- simulate 100 fault ruptures recorded at the 56 receiver stations

synthetic ground motions

The low frequency component is defined by means of a wavelet of the form:

$$V(t) = 0.5 A_p \left[1 + \cos\left(\frac{2\pi f_p}{\gamma_p} (t - t_0) \right) \right] \cos\left[2\pi f_p (t - t_0) + \nu_p \right]$$

this is a **four-parameter** wavelet whose parameters are randomly sampled:

- A_p: amplitude of the velocity pulse **A_p=0.9 PGV**:

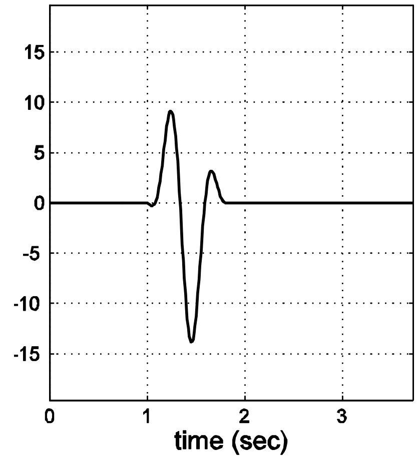
$$\log \mathrm{PGV} = 2.040 - 0.032 r_{\mathrm{rup}}$$

- f_p: pulse frequency:

$$\log T_p = -2.9 + 0.5 M_W$$

- ν_p: the phase angle, normally distributed

- γ_p: the number of cycles, normally distributed



rigid block structures

Following the work of Housner (1963), the equation of motion of a rocking rigid block is:

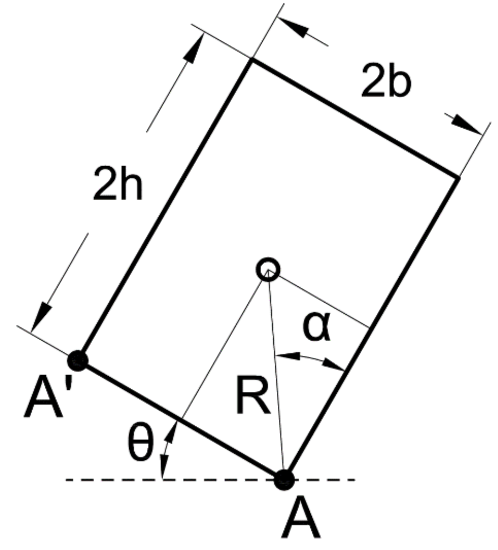
$$\ddot{\theta}(t) = p^2\left[-\alpha \operatorname{sgn}\left(\theta(t)\right) + \theta(t) - \ddot{u}_g(t)/g\right]$$

the geometry of the block is fully described by the **slenderness angle *α***:

$$\alpha = \operatorname{atan}(b/h)$$

and the **frequency parameter *p***:

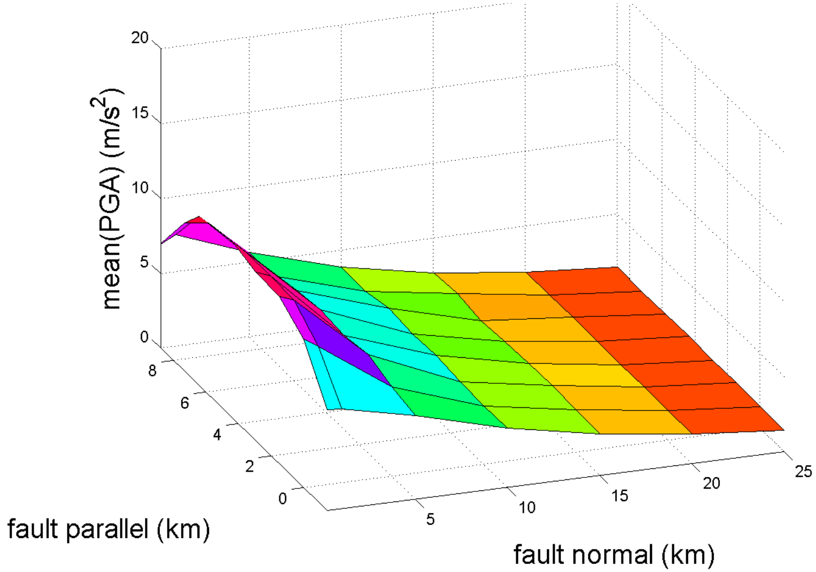
$$p = \sqrt{\frac{WR}{I_0}} = \sqrt{\frac{3g}{4R}}$$



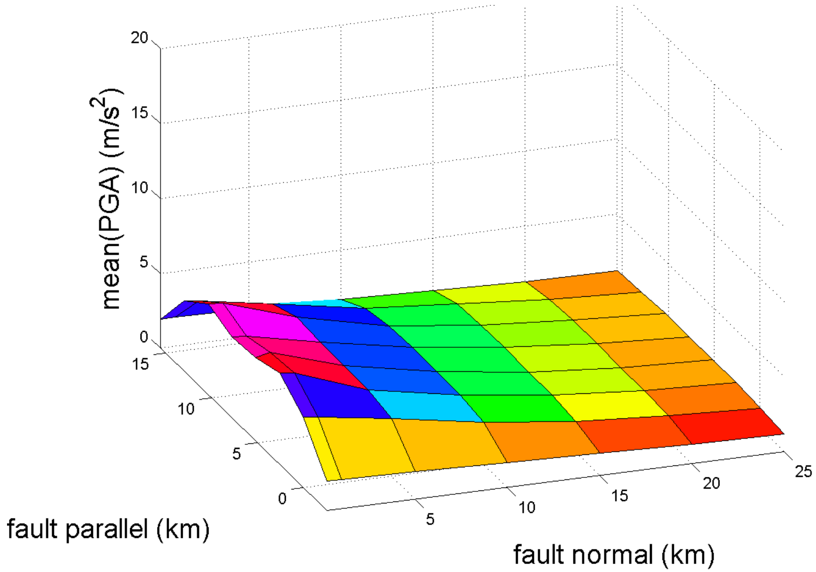
we examine rigid block structures with aspect ratio λ = h/b = 2, 3, 5, 10 and frequencies p = 1.5, 2.5, 5.0 – **12 block configurations**

peak ground acceleration

M_w=6



M_w=7

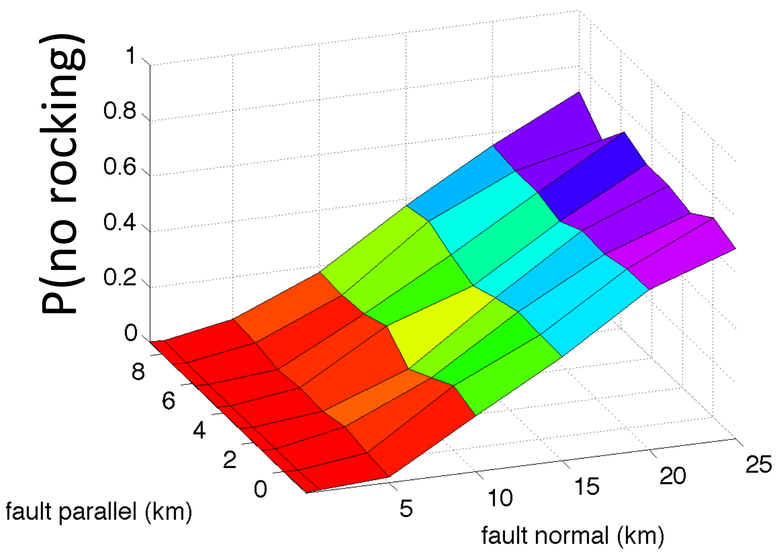


Distribution of the **mean peak ground accelerations (PGA)**:

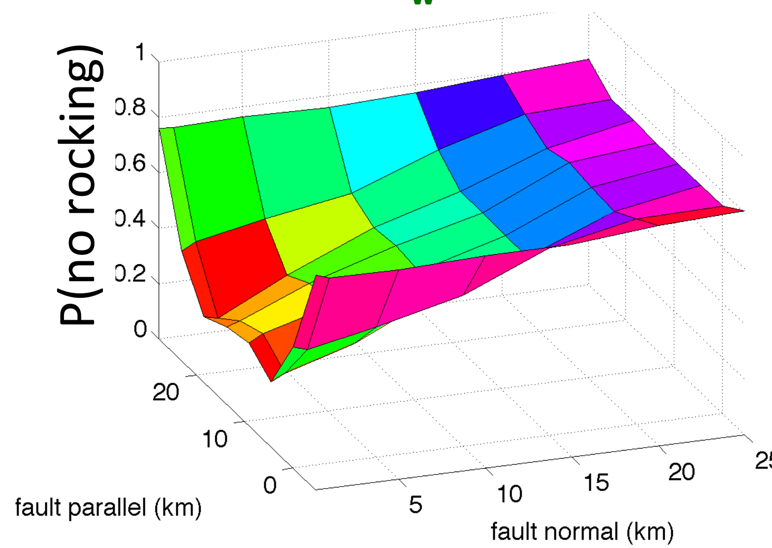
- larger PGAs close to the epicenter (as expected)
- events of **smaller magnitude M_w produce larger PGAs**

no rocking initiation

M_w=5.5



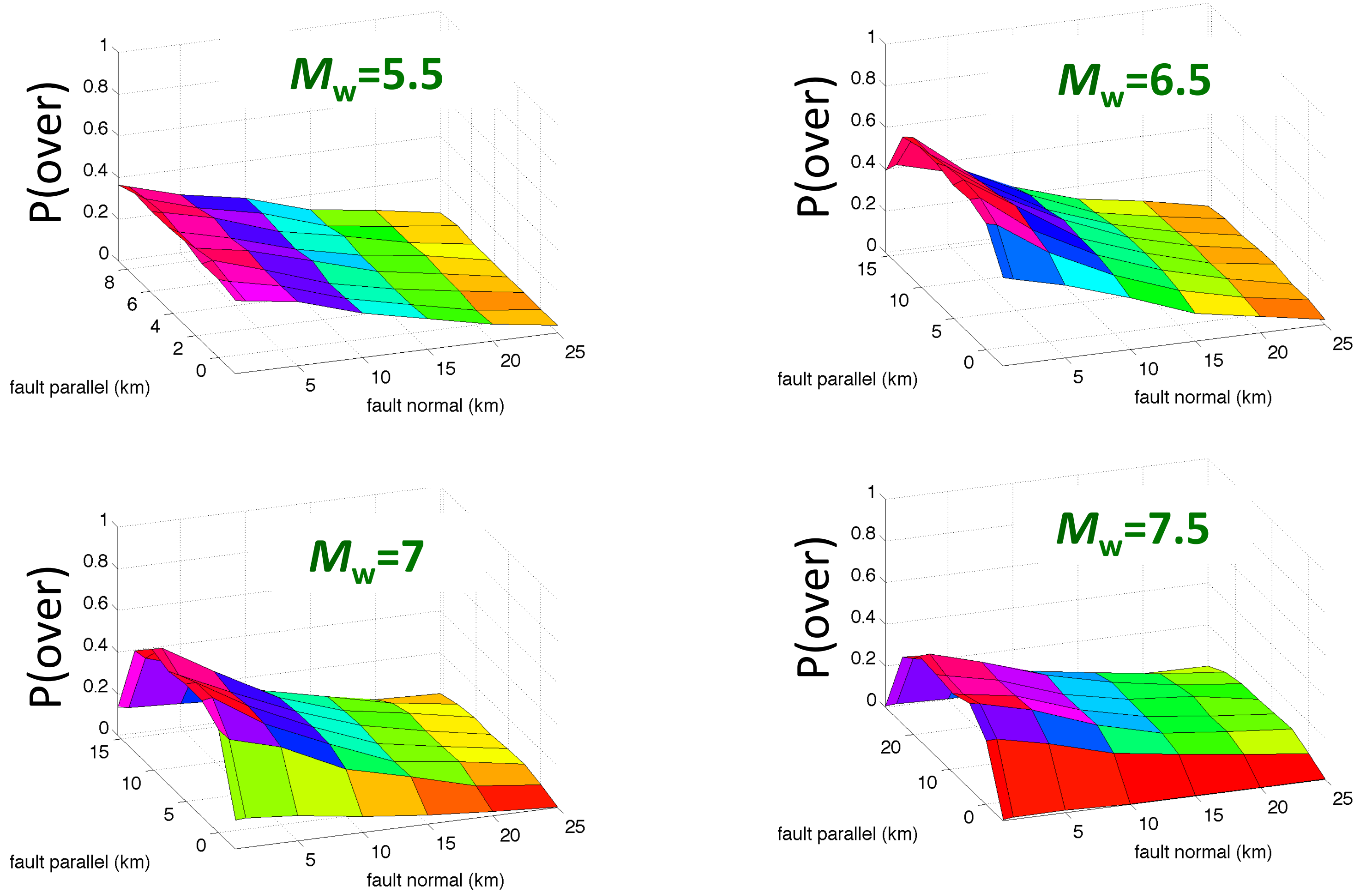
M_w=7.5



rocking is initiated only if **PGA/g tanα ≥ 1**, thus:

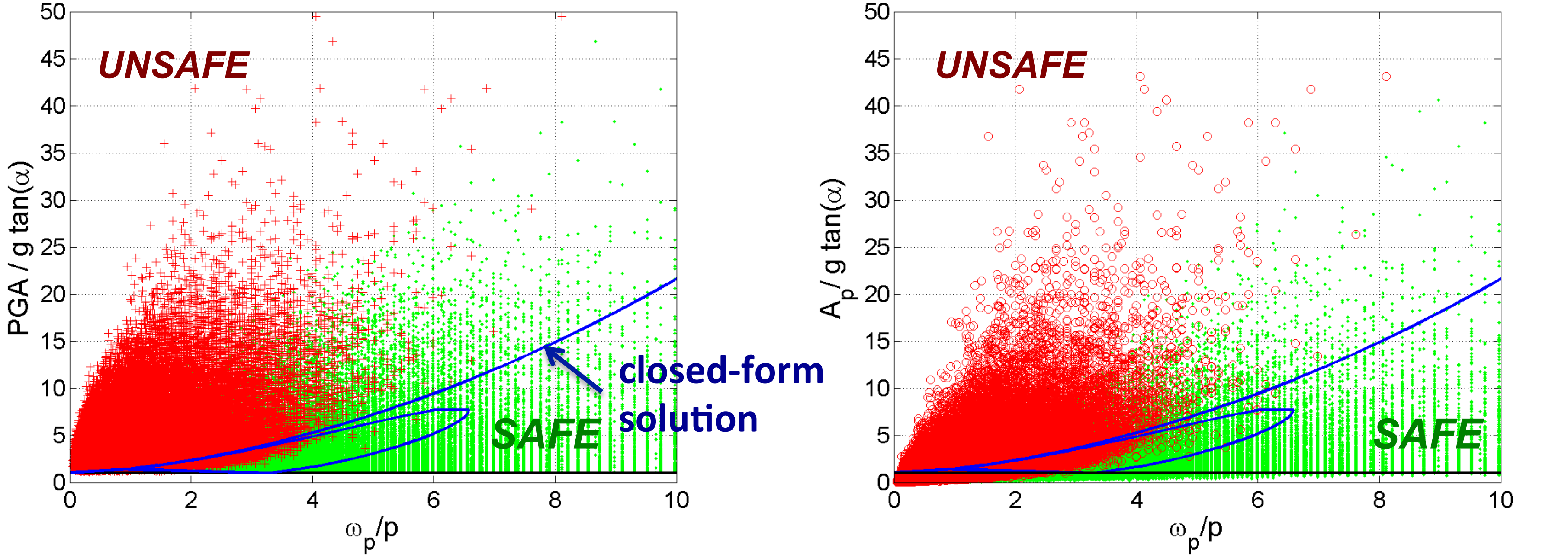
- for M_w=5.5 all ground motions set the blocks to motion, but this is not the case for the M_w=7.5 events
- at large distances, most probably, the block will remain at rest

overturning probability



Overturning probabilities do not follow the trend of PGAs, i.e. small values for M_w=5.5, maximum for M_w=6.5 and decrease again for M_w > 7.0

overturning spectra



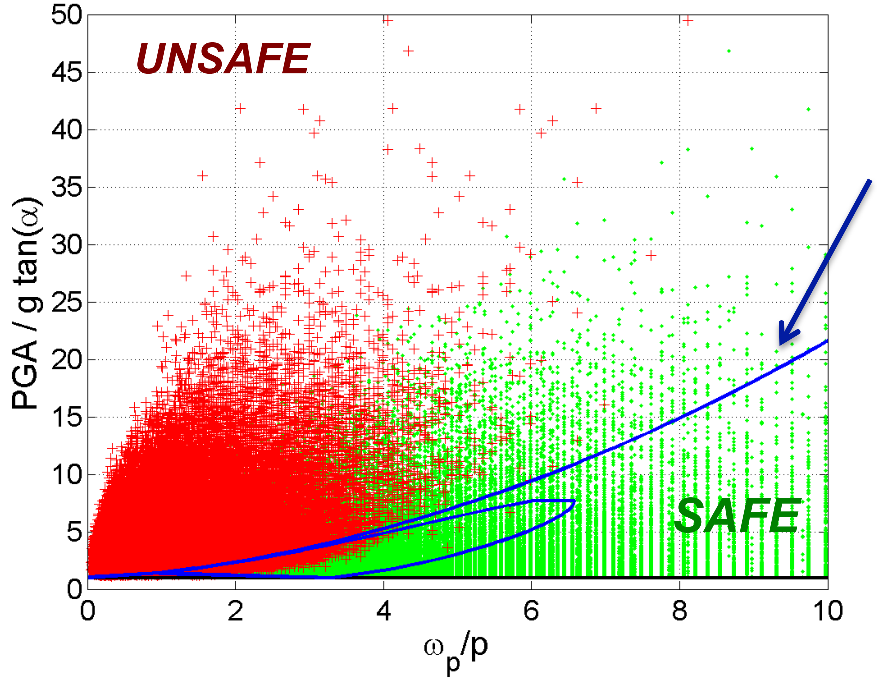
we present results in the form of **overturning spectra**: i.e. graphs of frequency ω_p/p versus amplitude **PGA/gtanα** or A_p**/gtanα**

PGA/(g tanα) is preferable over A_p/(g tanα):

- easier to calculate
- respects the condition that rocking will immense only if PGA/(g tanα) ≥ 1.

overturning spectra

small blocks OR
low frequency pulse

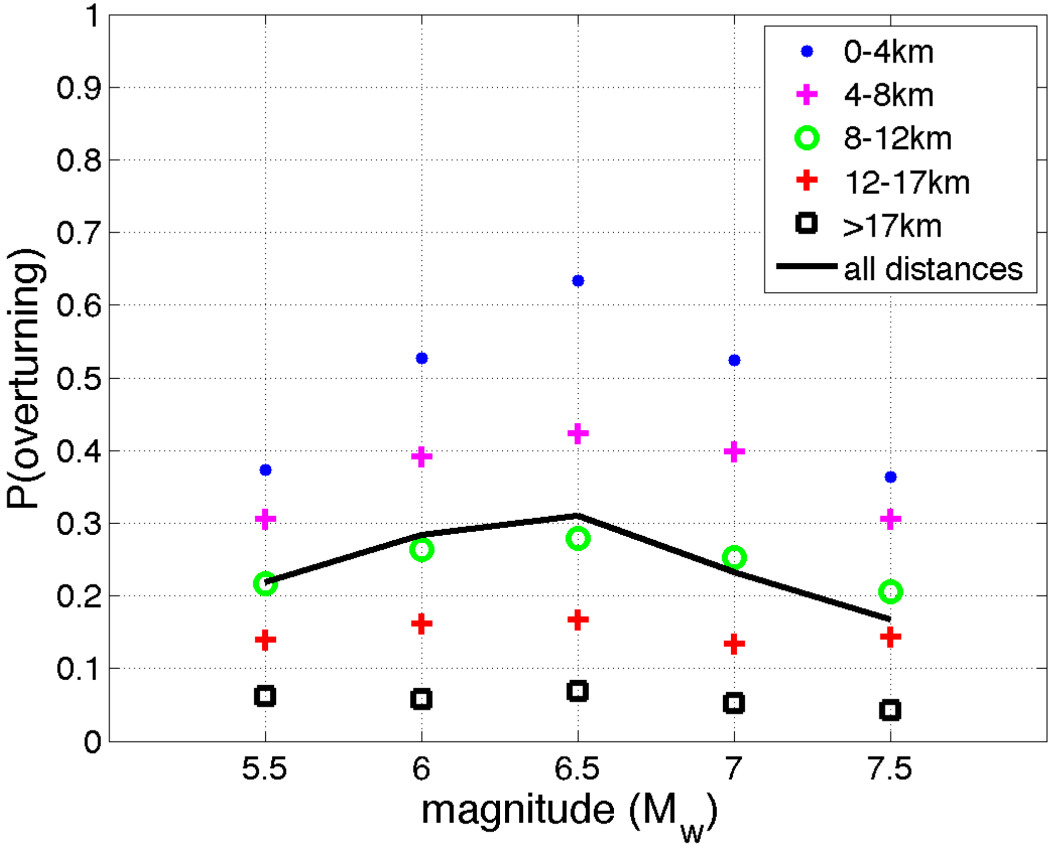


closed-form solution
(Dimitrakopoulos & DeJong 2012)

large blocks OR
high frequency pulse

- many blocks **on the "unsafe" region do not overturn**
- For large ω_p/p values **overturning is rather improbable, especially for ω_p/p ≥ 8** (regardless of the PGA)
- **sinusoidal pulses are overall more conservative,** especially for ω_p/p ≥ 6.

effect of distance

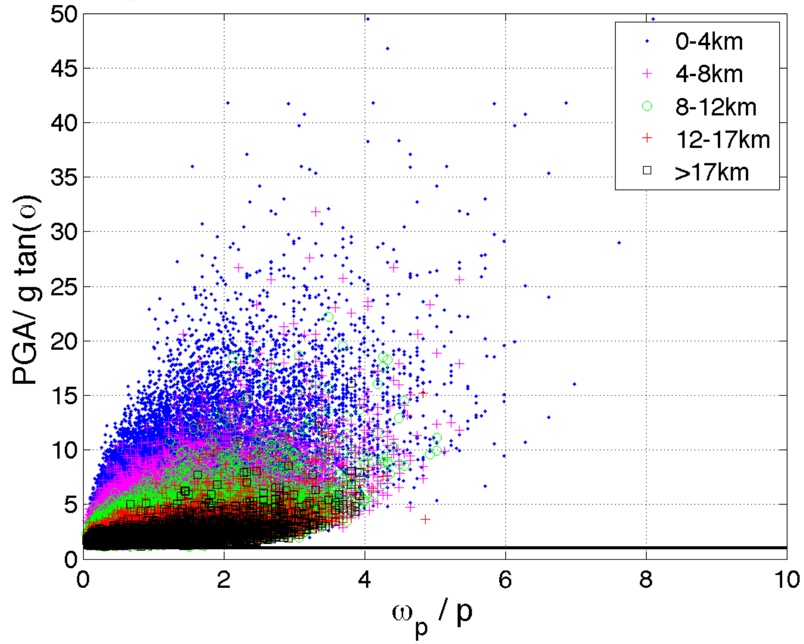


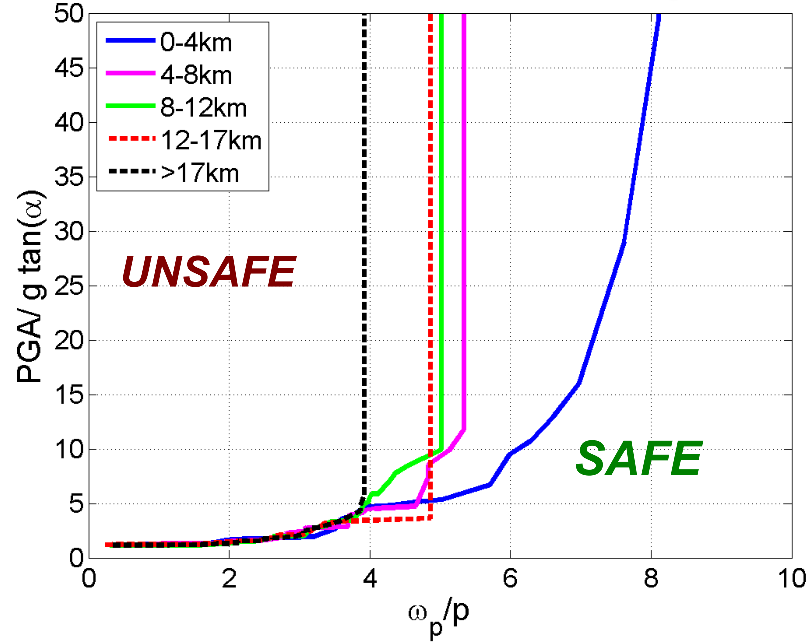
- Very **high overturning probabilities close to the fault** and very small as we move away
- **Magnitude 6.5 is the most critical** (compare to M_w=5.5 and M_w=7.5)

effect of distance

small blocks OR low frequency pulse

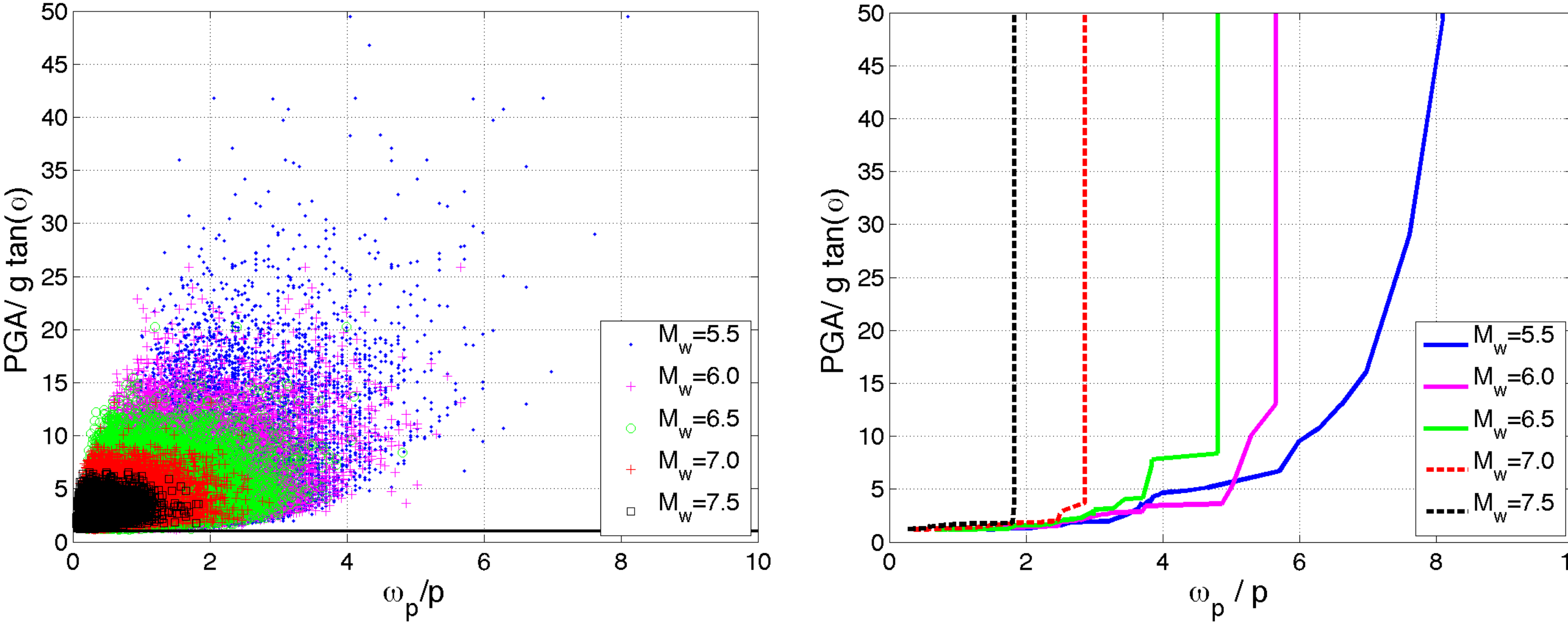
large blocks OR high frequency pulse





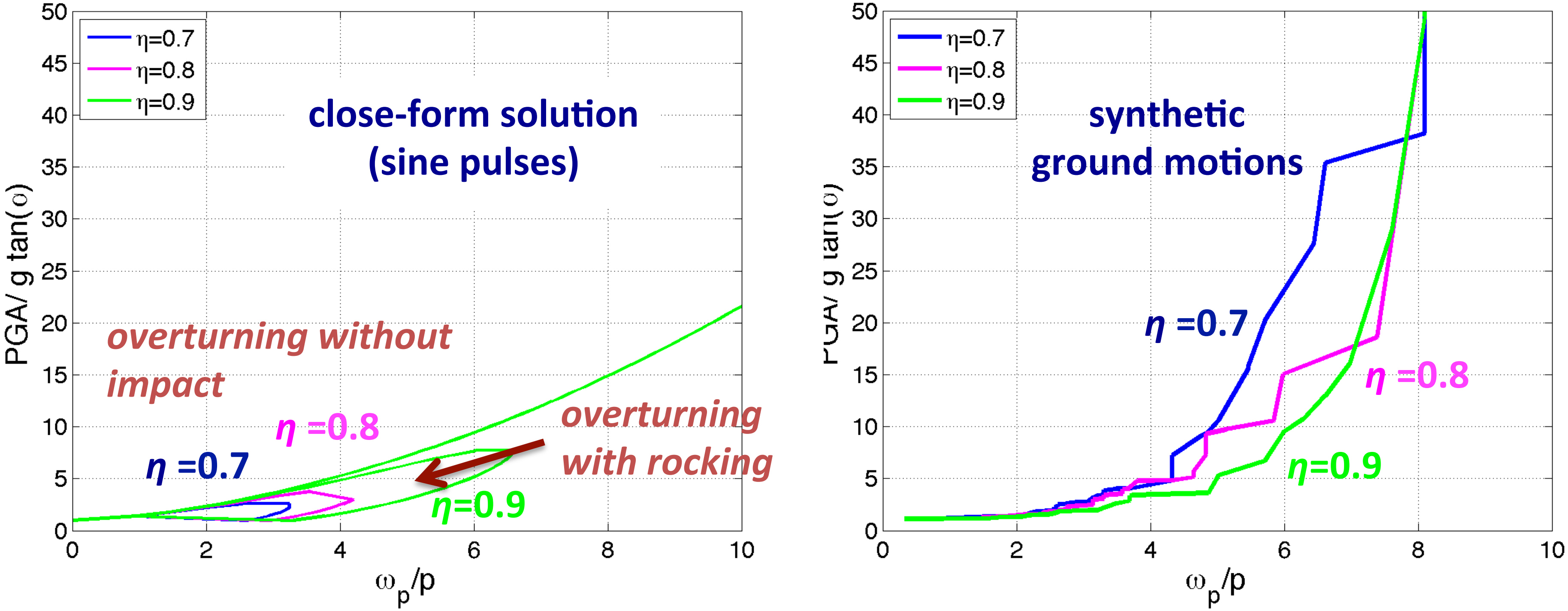
- the number of blocks that overturn decrease with distance
- distance seems important only when $\omega_p/p \geq 4$

effect of magnitude



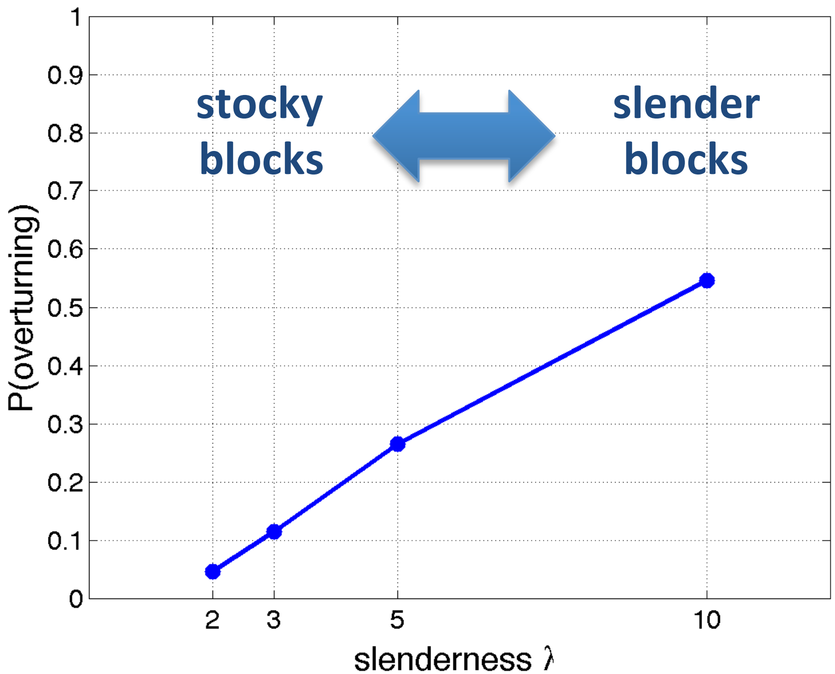
- distinct differences looking at different M_w events (threshold curves)
- for a given block, *p* value -> only small values of ω_p/p can be attained for large M_w, hence the threshold curves move to the left as M_w increases
- for large M_w the blocks overturn for a small PGA/g tanα, **thus for large M_w if rocking initiates, the block will most probably overturn**

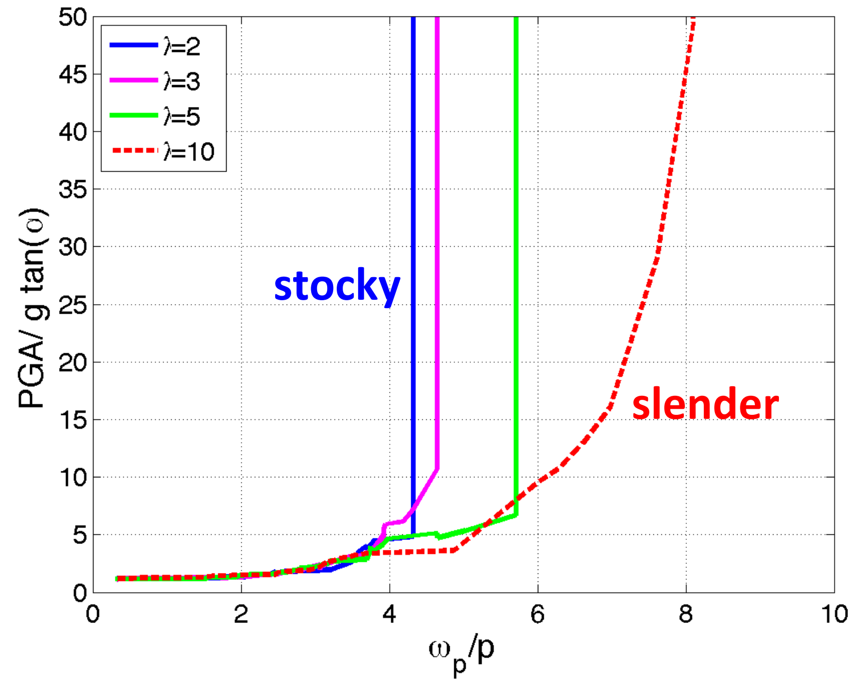
coefficient of reinstitution



- closed-form solutions from sine pulses → ***η* is of some minor importance when overturning with rocking occurs**
- when synthetic records are considered, **small effect on the overturning probability for *η* = 0.8 and *η* = 0.9, some sensitivity for *η* = 0.7**.
- In all, we don't need to "exactly" know the value of *η*

block slenderness

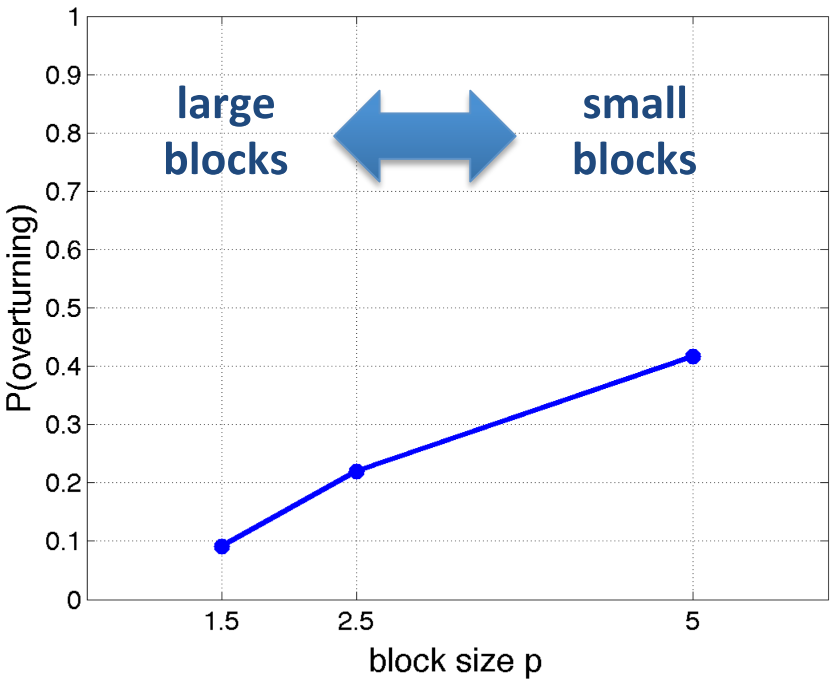


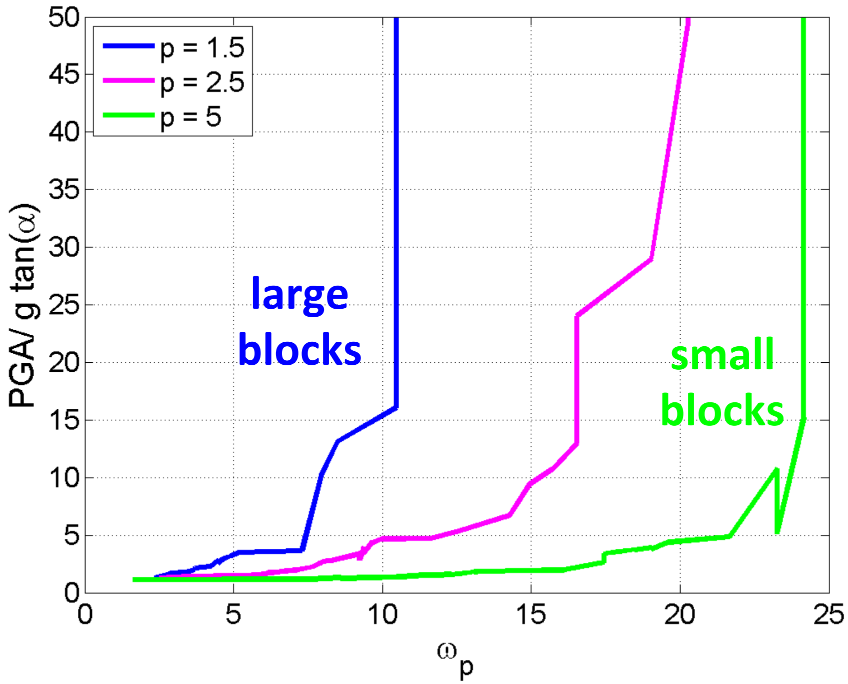


effect of the block slenderness *λ* = *h*/*b* :

- λ = h/b values considered: 2, 3, 5 and 10 (α = 26.5, 18.4, 11.3, 5.7)
- slender blocks are susceptible to overturning since small PGAs can set them to rocking
- slender blocks topple for significantly smaller α, therefore, they are more vulnerable to small-period ground motions (the threshold curves move towards larger ω_p/p as λ increases).

frequency parameter





effect of the frequency parameter p = $(3g/4R)^{0.5}$:

- *p* values considered: 1.5, 2.5 and 5 (*R* = 3.3, 1.18, 0.30)
- Scale effect – large blocks are more susceptible
- Small blocks overturn even for high-frequency records for which the large blocks are safe

Thank you for your attention