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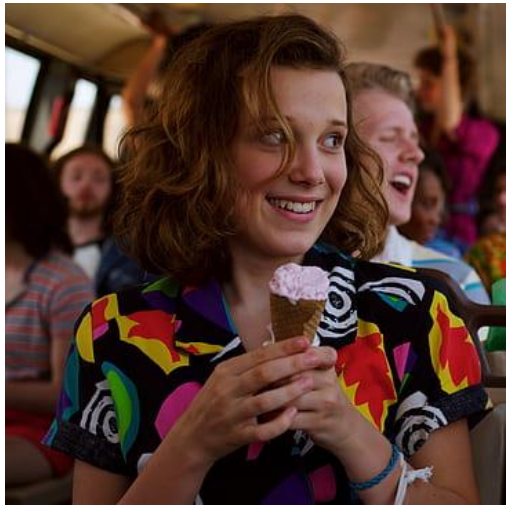
STRANGER THINGS IN SEISMIC RESPONSE AND STATISTICAL TOOLS TO RESOLVE THEM

SECED 2023, Cambridge, 15 September 2023

The era of low hanging fruit



- Remember when life was **simple**?
- **Ice cream**, long vacations,……
- ……**sinusoidal** motions, single pulses
- Back when **analytical** methods still worked?
- When 2-3 ground motions were **enough**?
- That time has been **over** since the 90’s


WELCOME
TO
HAWKINS

The vanishing of simple answers

- We now live in a **very different** era
- Statements that can be proven **unambiguously** are already done
- What is the **influence** of period? Strength? Ductility?
- Plan asymmetry? Soil site characteristics?
- This was our **familiar** structural /geotech world
- where we **thought** we had all the answers…
- ……but it has now **vanished**

The Upside Down

- It is the **fault** of seismology (pun intended)
- Why oh why do we have to deal with **multiple** accelerograms?
- Magnitude, distance, epsilon, **kappa**, directivity, duration
- They are exhausting the Greek alphabet (and us together)
- But do **all** these parameters matter?
- Do we have to **account for all** in our analyses?
- How to find out?

Statistics, do you copy?

- How does an engineer get answers in the **Upside Down** world of seismology?
- What matters to **us** (think acceleration spectrum)
- What matters to **them** (think Fourier spectrum)

- How to bridge this border?
- How to reach engineering conclusions that **account for** seismological facts?
- Grab that radio set and call **statistics** for help!

Statistics, does X matter?

- We can translate this as:

"**Is the effect of X statistically signficant**"?

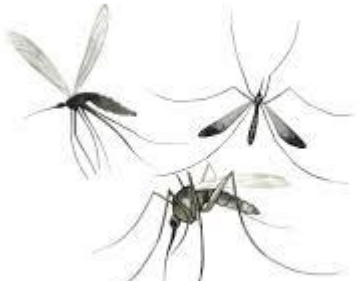
Aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaahhhhhhhhhh

- This is the realm of **hypothesis** testing and **p-values**
- Pure frustration for generations of **young** students and **veteran** researchers
- There are actual papers of **love & hate** on p-values
- …and the results can be surprising. Try food!

Food and cancer

- Eating tomatoes/dark chocolate/Ω3 fats/red wine
- Beneficial or detrimental?
- Does it **reduce or incease** cancer risk?
- Look at Schoenfeld and Ioannidis (2013)
- Meta-analysis of **proper** randomized testing (not 10 samples!)
- **Unambiguous** statistical evidence that tomatoes **reduce** cancer risk
- Yay Greek salad!

Mosquitos are no joke



- But you need **several kilos** of tomatos per day for, say, 10% reduction
- I can see some health problems with this
- If we need **x1000 zoom** to see an effect, perhaps it is useless?
- Statistically, you should **watch out** for mosquitos when weighing!
- By sitting on you, they **increase** your weight (see Newton's laws)
- We are engineers
- …so don't forget **practical** significance

To pair or not to pair

- To do proper **statistical testing** you need to decide:
- Paired or independent samples?
- Think **medical** research
- Paired = (monozygotic) **twins**!
- Independent = samples arranged for **similar** (macro) properties
- Paired samples offer **high** power (= small sample needed)
- But how to get them for earthquake engineering?

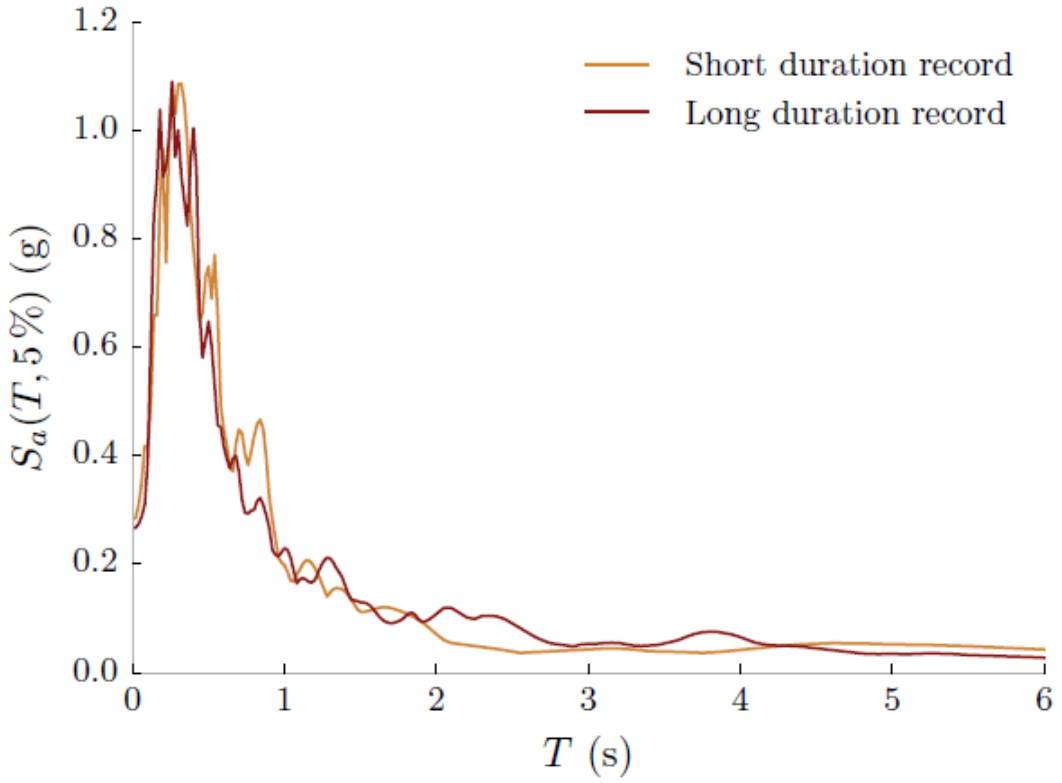
Structure vs ground motion

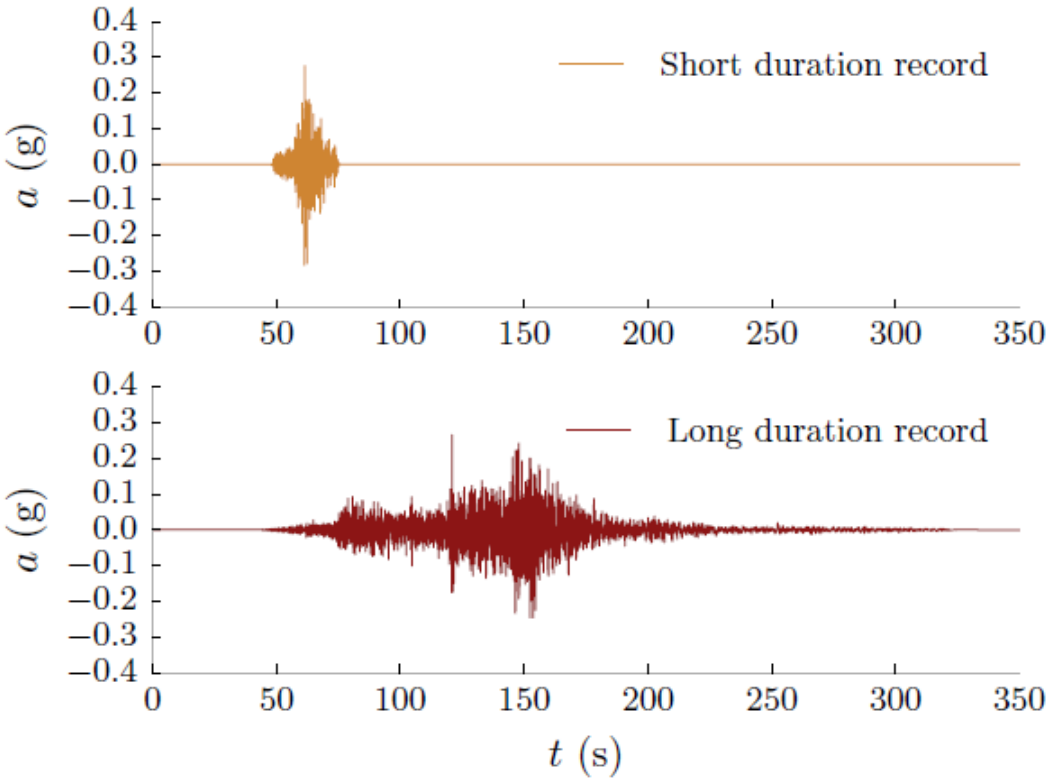
- Super easy if researching effects of **structural** properties:
  - Use same record suite (= twins)
  - Vary the structure (= treatment)
  - Compare response pre/after treatment

- What if researching effects of **ground motion** characteristics
  - duration
  - directivity
  - …

- Can you create twins of ground motions **bar one** characteristic?

Thank you Chandramohan, Baker & Deierlein!

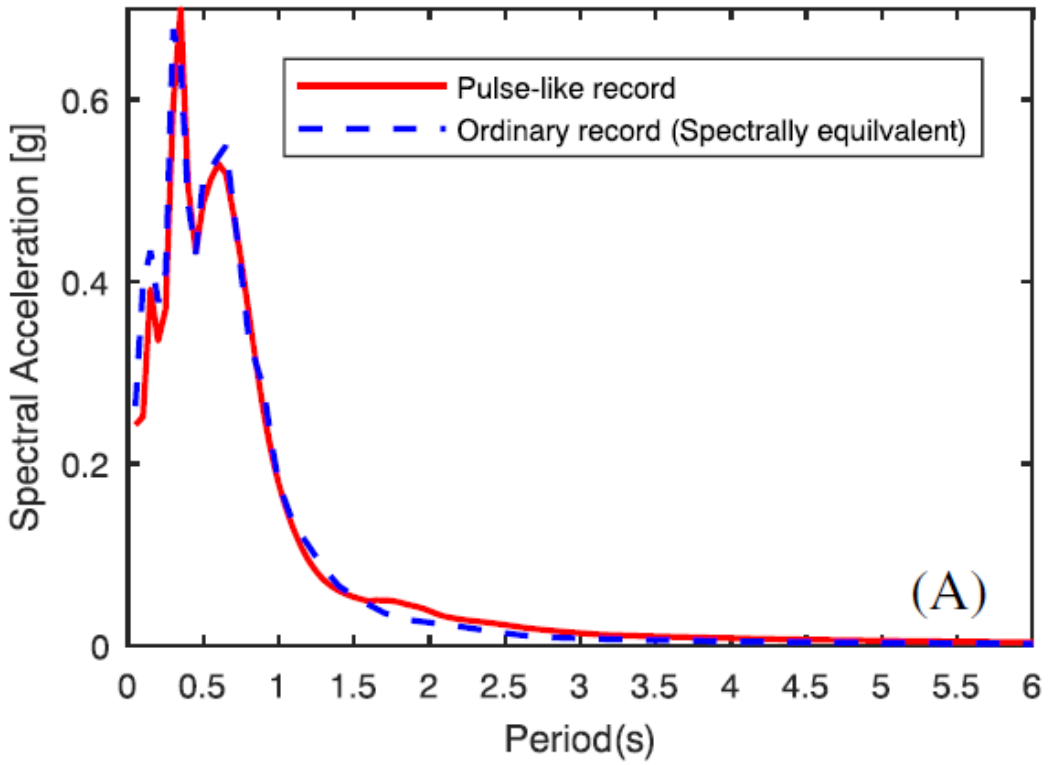


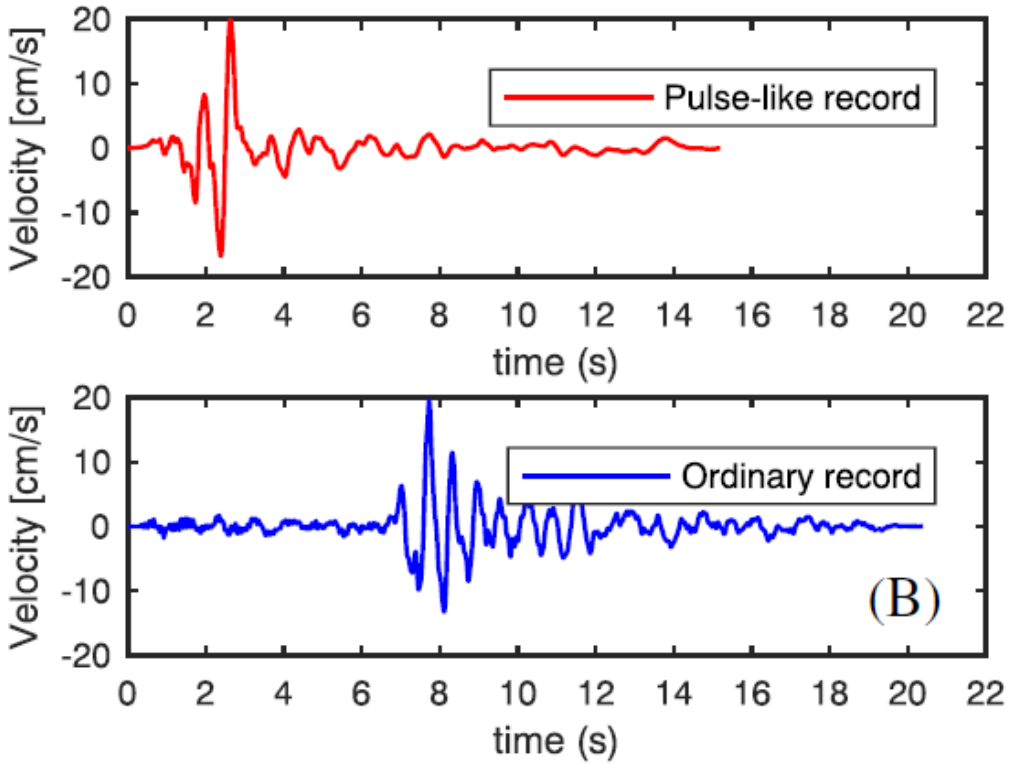


- Engineers care about spectra (=**DNA**!)
- Search for records with **"same" spectra** and different "characteristic"
- **Spectrally-matched** pairs!

- Long versus short **duration** twins
- Apply both on same structure
- Check for **changes** in response

Thank you Kohrangi et al.!



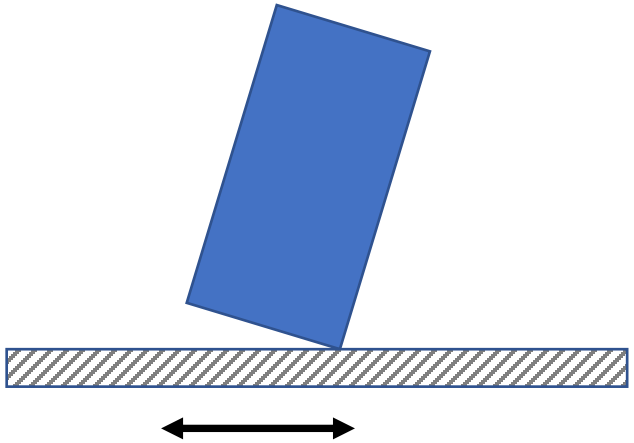


- Pulse versus non-pulse records
- **Spectrally-matched** pairs!
- Same idea

- Check for **changes** in response

Enough hand-waving
Time to dive in

Two test cases of little intuition



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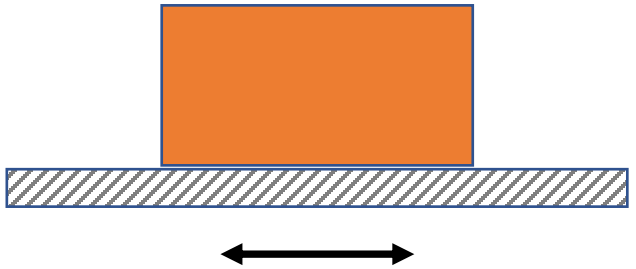


Rocking!

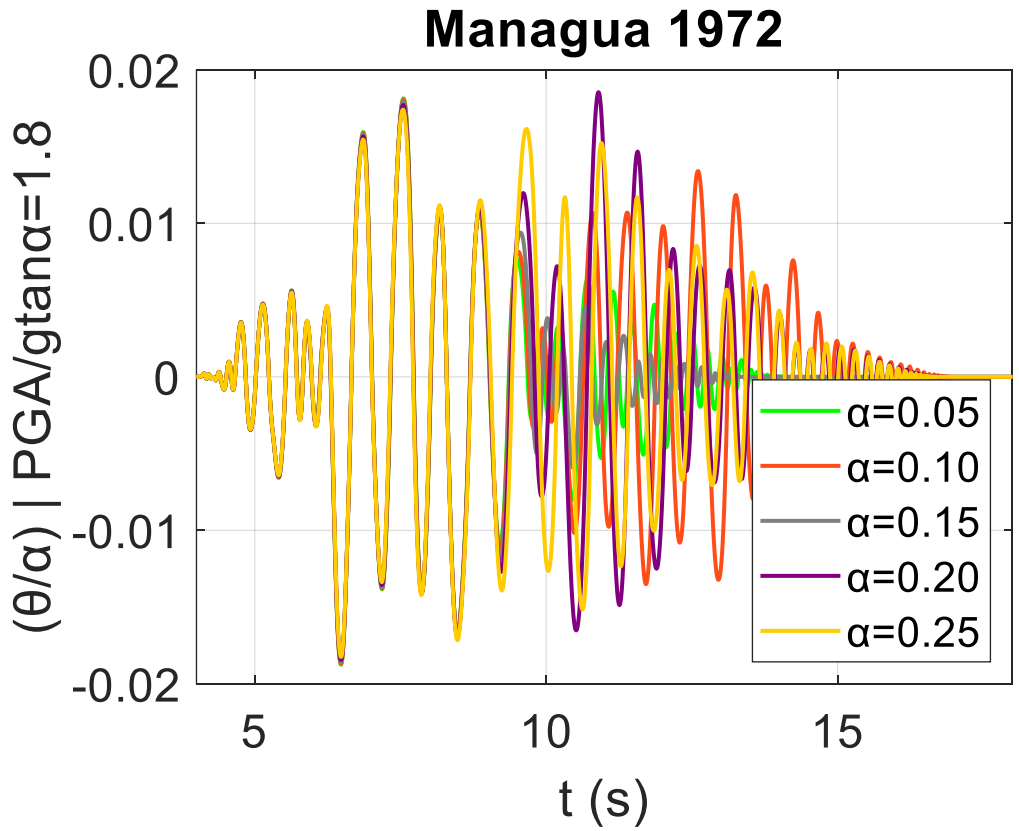
Sliding!

Does the **shape** of the block matter?

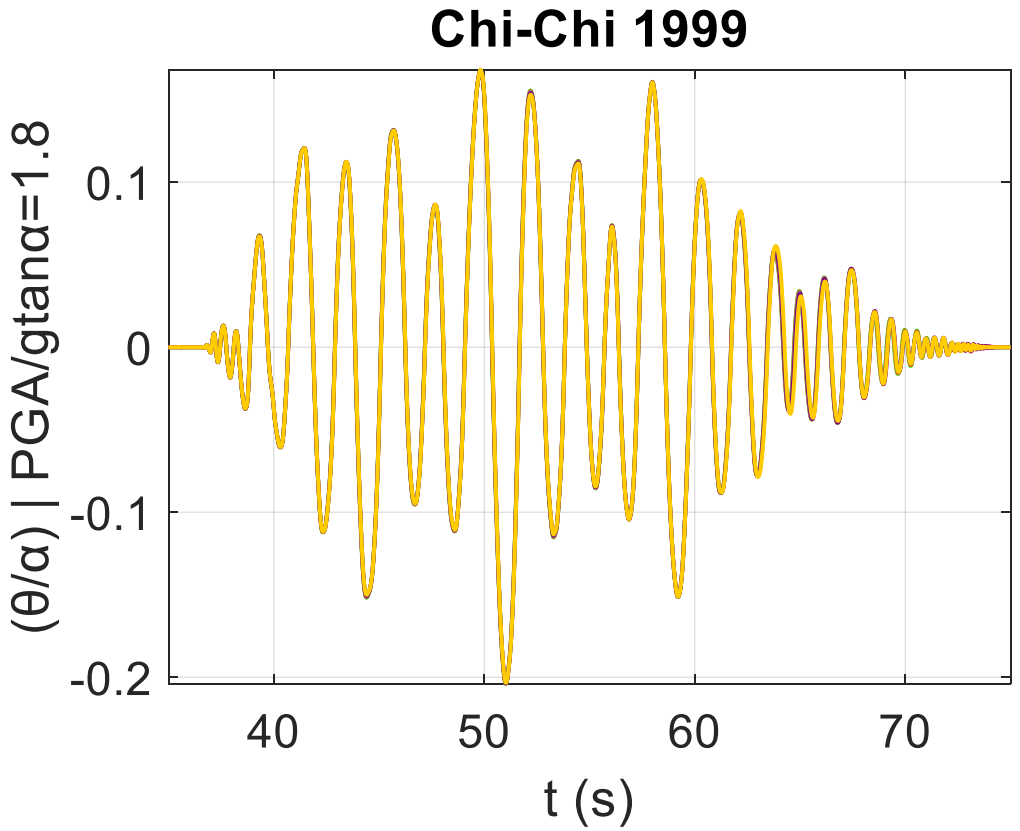
Does the **nature of motion** matter?

The battle of the rocking block

Level 1: Individual response histories – Non-pulsive



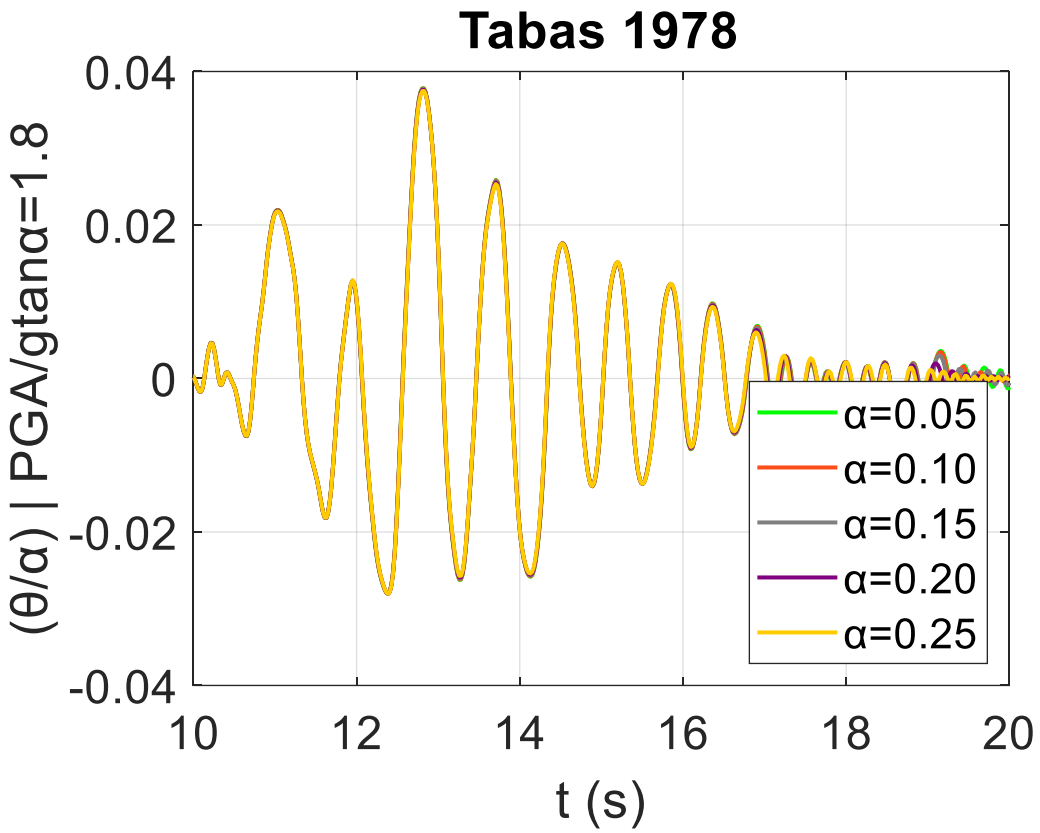
Does the block shape matter?
Seems so without pulses



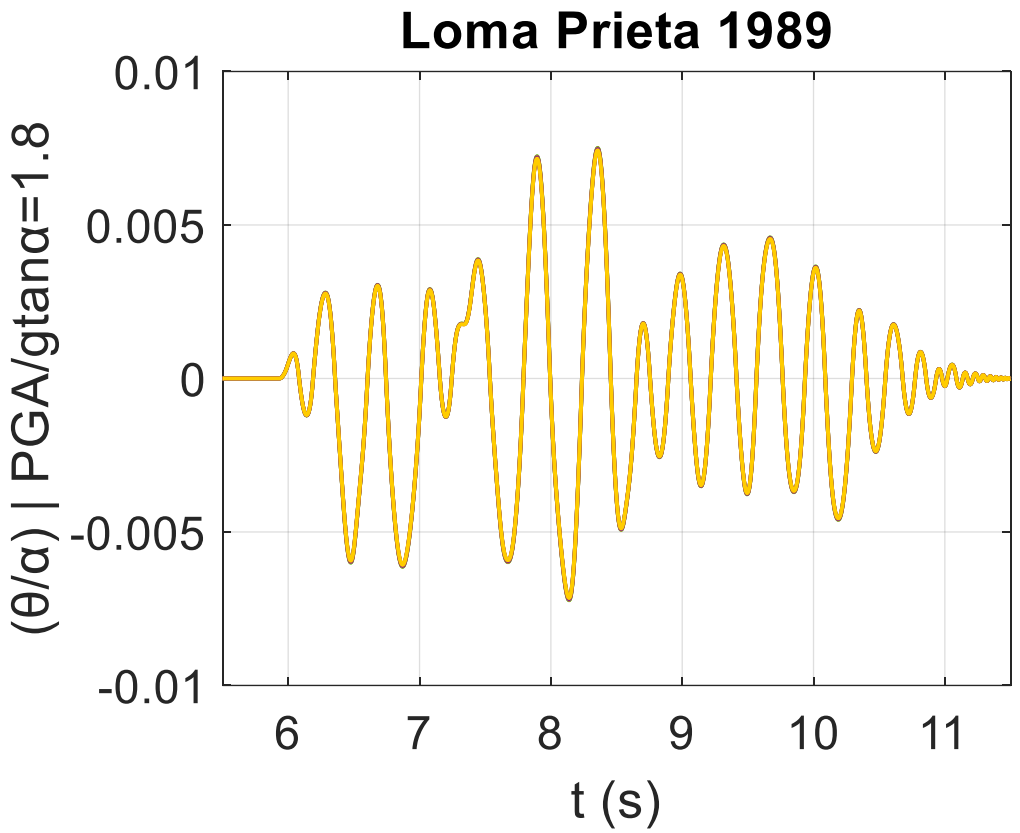
Here it does not matter!

Lachanas C.G., Vamvatsikos D., Dimitrakopoulos E.G. (2023). Statistical properties of simple rocking block response, EESD

Level 1: Individual response histories – Pulsive

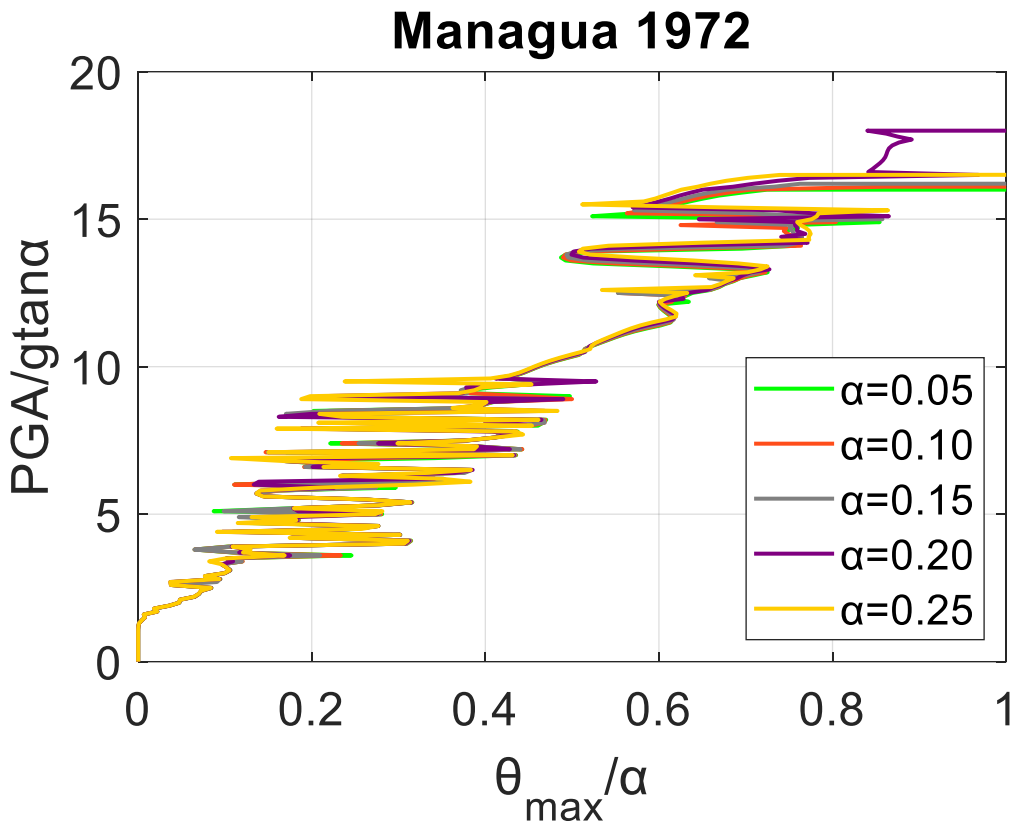


Does the block shape matter?
Little difference with pulse!

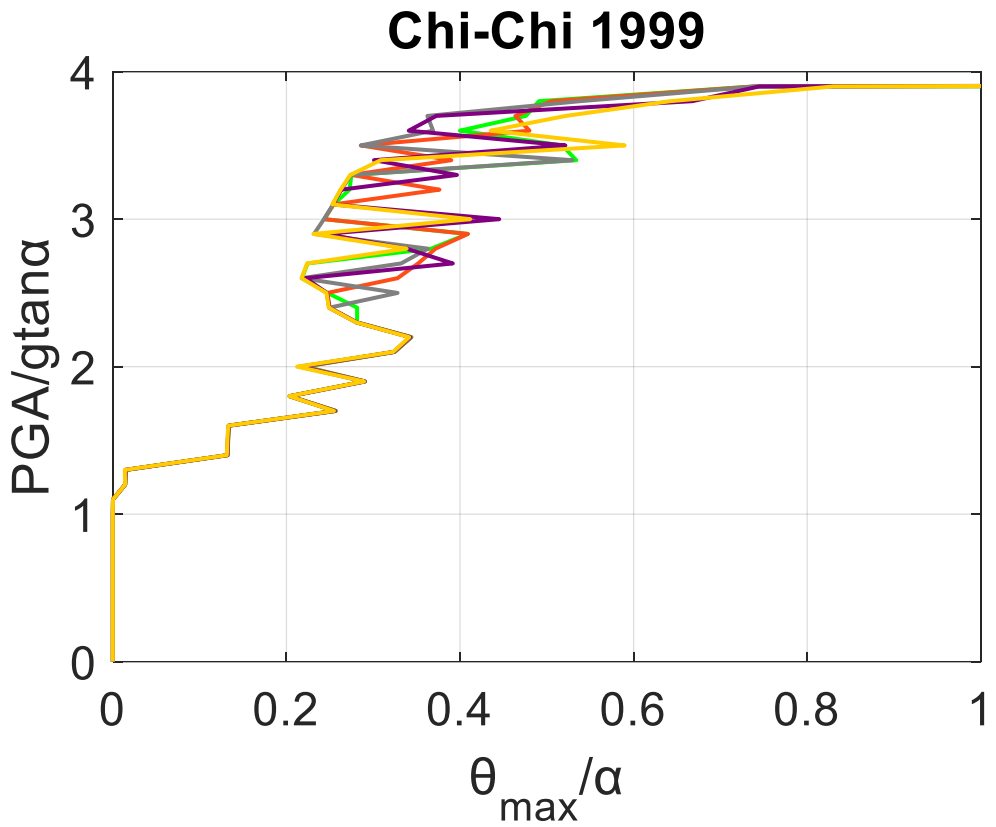


Still pretty good match!

Level 2: Individual response history maxima – Non-pulsive

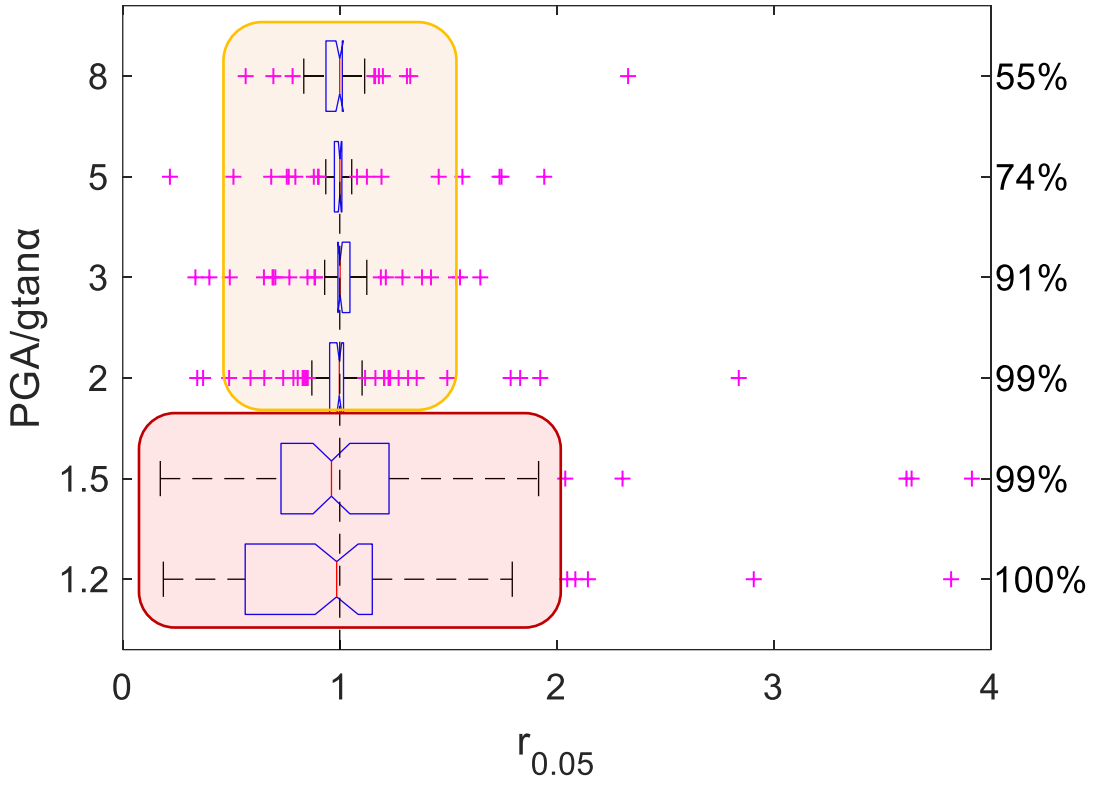


Minimal differences

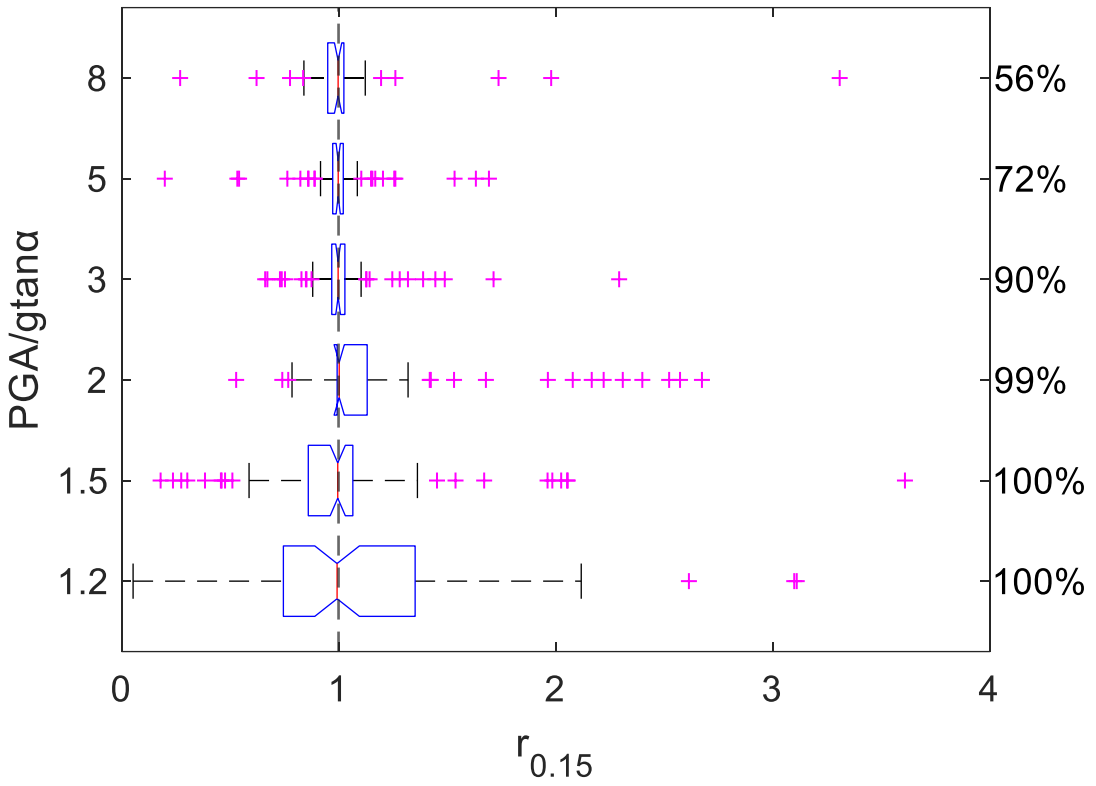


Still pretty good match!

Level 3: Ensemble paired statistics

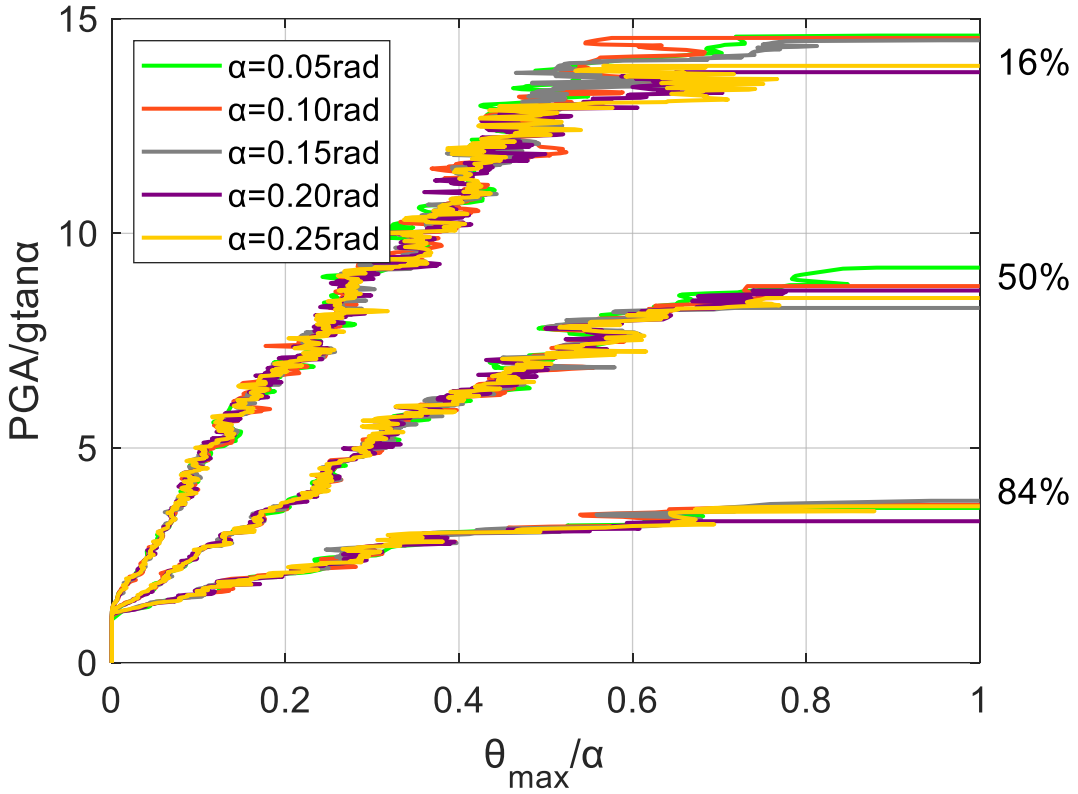


Boxplots of response ratios from **different** blocks (same *p*)
Minimal difference **up high**

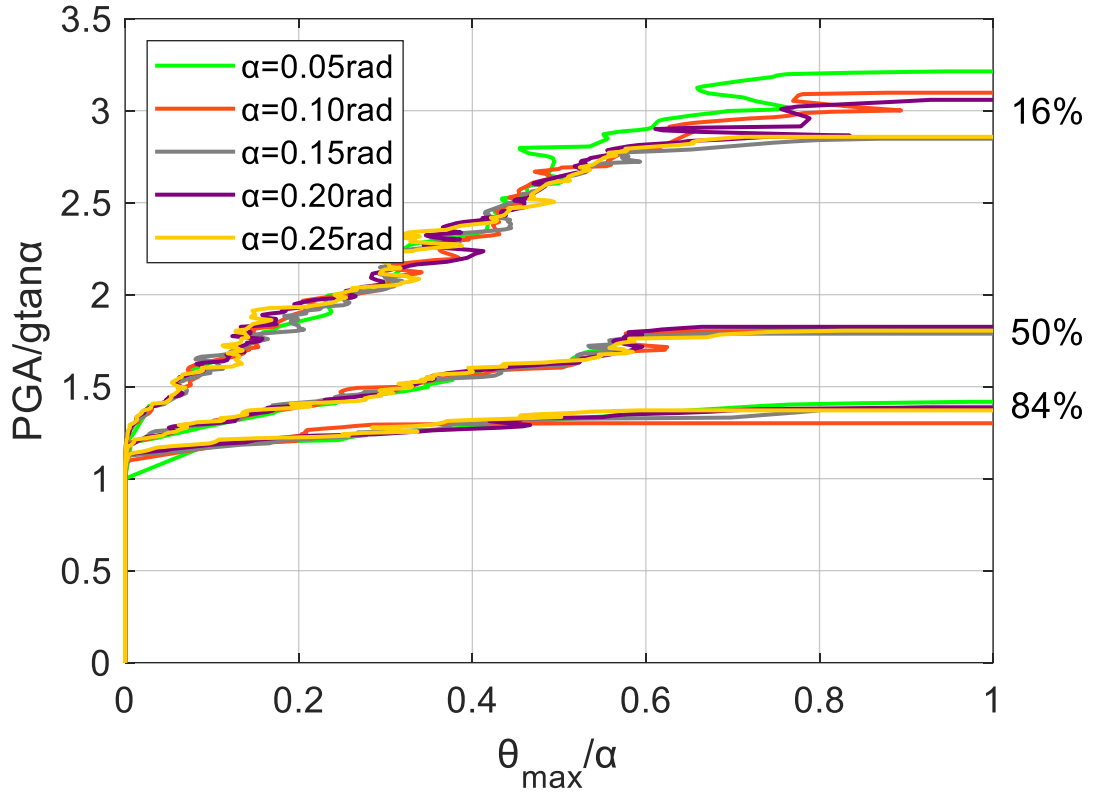


Some difference **down low**
Significant?

Level 4: Ensemble unpaired statistics



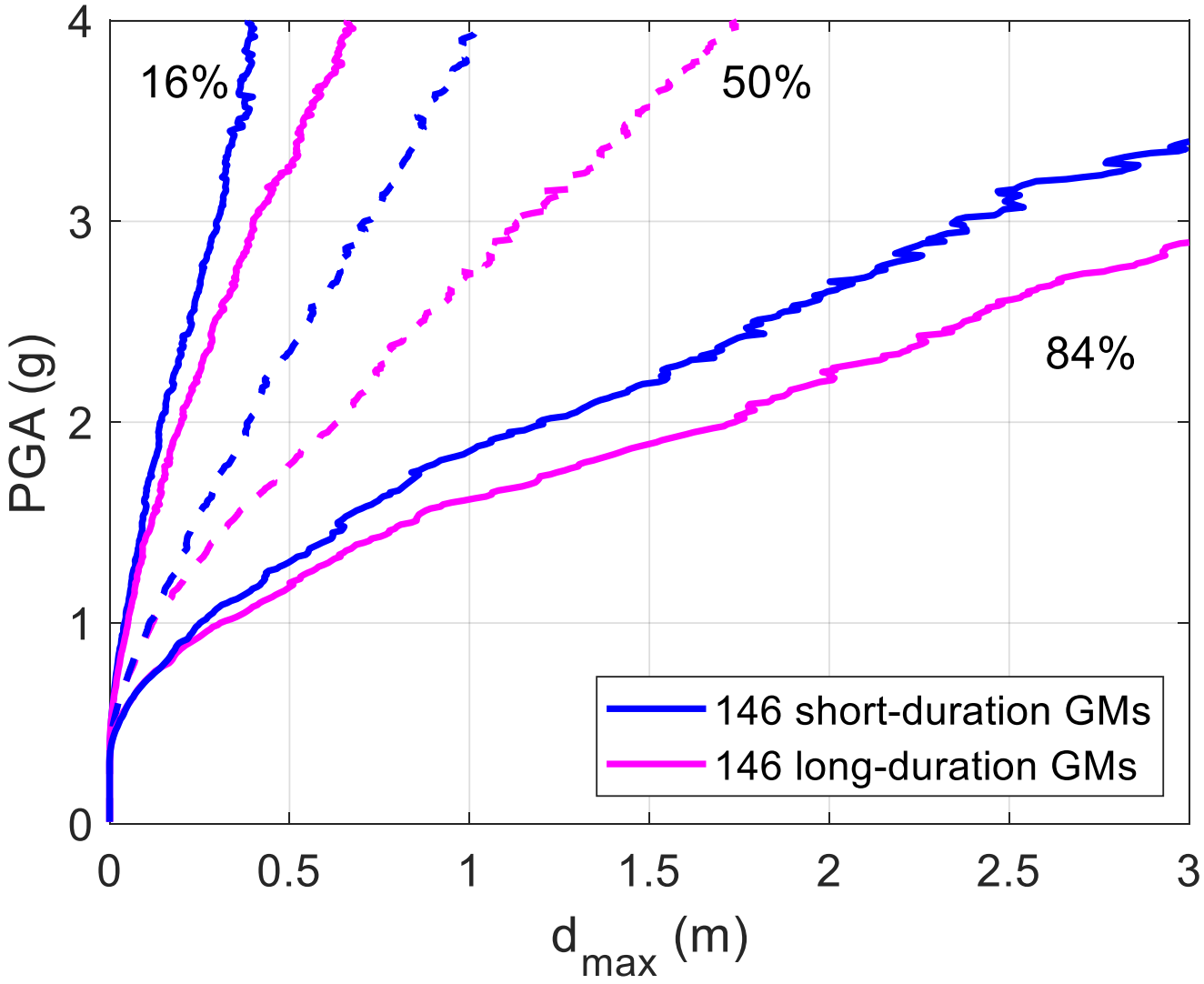
No difference for $p = 1\ s^{-1}$
Low-power test, but adequate



Same here for $p = 3\ s^{-1}$!

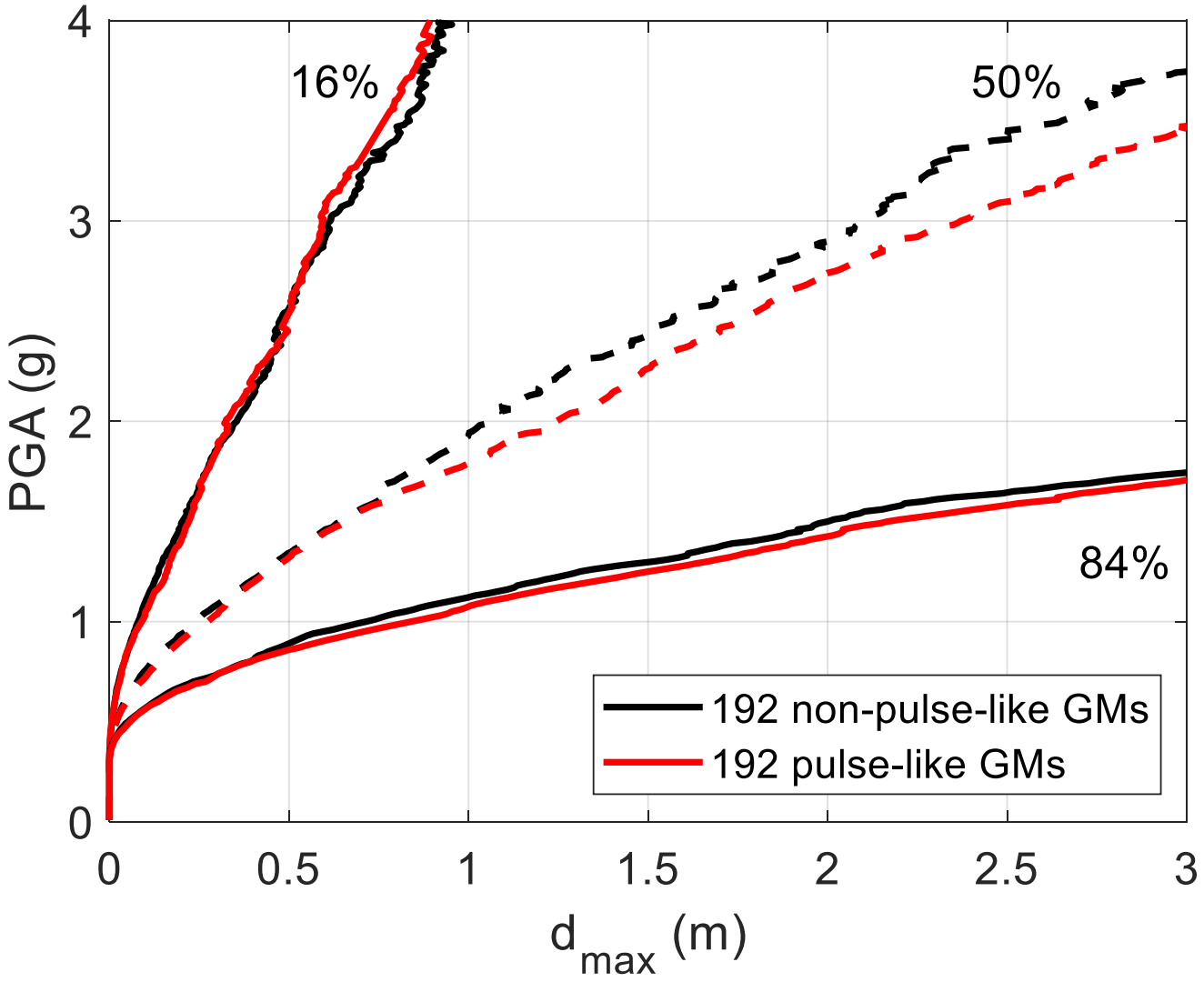
The pairing of the sliding block

Does duration matter?



- Spectrally-matched **long/short duration** pairs
- 16/50/84% fractile IDAs
- Oooops!
- Duration **cannot** be discounted
- Cannot mix **crustal & subduction** zone motions without care

Does pulsiveness matter?



- Spectrally-matched **pulse/no-pulse** pairs
- 16/50/84% fractile IDAs
- Hmmmmm
- Pulses are **not important**
- Can discount **near/far field** issues


♪ A never-ending story ♪

A NeverEnding Story

Engineers will **always venture** into the Upside Down of Seismology

Figuring out **what matters** and what not is important

Site, fault mechanism, duration, pulses, structural system?

Paired record testing is our best friend

Remember: **Monocausal** explanations have been researched out (or **hiding** really well)

A NeverEnding Story

When it comes to **"Does X matter"**

the best **universal** answer for earthquake engineering is

"It depends"

Acknowledgements

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