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Record Selection for Nonlinear Time History Analyses

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Current Best Practice*:

·Disaggregate PSHA at Sa (T) at p_o, say, 2% in 50 years, by M and R: $f_{M,R|Sa}$.

· Select Records: from a "bin" near mean (or mode) M and R. Same faulting style, hanging/foot wall, soil type, …

· Scale the records to the UHS (in some way, e.g., to the $S_a(T_1)$).

*DOE, NRC, PEER, … e.g., see R.K. McGuire: "... Closing the Loop"(BSSA, 1996+/-); Kramer (Text book; 1996 +/-); Stewart et al. (PEER Report, 2002)

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Some Questions One Might Ask:

· Why disagg Sa (or IM)? Why not Drift (EDP) at p_o? Or E[Cost]*?

· Why not disagg and select on epsilon as well?

· Why use the mean (or mode) of $f_{M,R|Sa}$? Why not fraction of M's in sample proportional to $f_{M|Sa}$?**

· Scaling? Match UHS (or other "design shape") in "the mean"? Record by record (e.g., SRSS of S_a (T_i)'s)? Match S_a at T_1? Avg. Sa over period range?

*K. Porter ** Yucca Mountain 2003.

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Record Selection Procedures:

All of this care is taken (or at least thought about) because we think it is worth doing presumably because we think…... it might matter to structural response.

Lacking information from the engineers to the contrary, the seismologists have prudently assumed that all features (magnitude, faulting style, etc.) matter to response and so they do their best to provide accordingly.

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As a starting point, to address the question of "how best to select records?" from the structural perspective I propose:

An Iconoclastic Null Hypothesis:

It doesn't matter.

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Why does the Null Hypothesis that the choice of records is a non-issue* make sense as a starting point?

· Linear SDOF Oscillators: Duh.

· Linear MDOF Buildings:

Response ≈ SRSS

$$\approx PF_1 \cdot S_a(T_1) \cdot \sqrt{1 + (PF2/PF1 \cdot \mu_R \cdot \varepsilon_R)^2}$$

$$\approx k\, S_a(T_1)\,(1 + 1/2k'\, \varepsilon_R^{\,2})$$ with k' and $\varepsilon_R^{\,2}$ small.

where $R = S_a(T_2)/S_a(T_1)$.

*Provisos: no directivity issues, no shallow, soft soil issues, no basin effects.

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- Non-Linear SDOF Oscillators:

  Let's look: Directly by comparing responses from different record sets

- Non-Linear MDOF Buildings:

  Let's look: Directly, and Indirectly by studying the statistical dependence of response on event properties (such as M and R) "given $S_a(T_1)$".

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Non-Linear SDOF System Study Bases (Iervolino, 2003):

· System: Simple bilinear; T_1 = 1.5 sec; two yield strengths [selected to give median ductilities of about 2.5 and 6.5]; second stiffness = 3% of first.

· "Target" Event: M = 7.0; R = 20 Kms. [Note this is more restrictive than a real case when more than one event will contribute to IM or EDP hazard.]

· Estimate of EDP Reality: Non-linear dynamic results from all PEER catalog records (both components) in scenario [M = 6.7-7.3; R = 15-25km; C-D soil] [called henceforth the "Target record set"; details on request];

· First-Order, or Median, Confirmation Sought: Therefore records have been scaled to 0.17g [the median of this target record set]; [This is not necessary, but it gives virtually the same median EDP (Shome, et al.; and confirmed here) and smaller dispersion, hence stronger significance tests on the median.]

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Non-Linear SDOF System Study (Cont'd):

First: We get results representing reality.

Then: What happens when we try other sets of records?

1."A" Set(s). *Under the null hypothesis*,the "best" set would be n records from selected the PEER catalogue randomly (irrespective of the target event). The largest source of potential commonality in a record catalogue is the event, of which there are comparatively few. Therefore these sets were chosen randomly subject to constraint that there were no (or rather the minimum possible) records from the same event [from all PEER Soil C-D records with $6.3<M<7.3$, $15<R<50$km; details upon request.]

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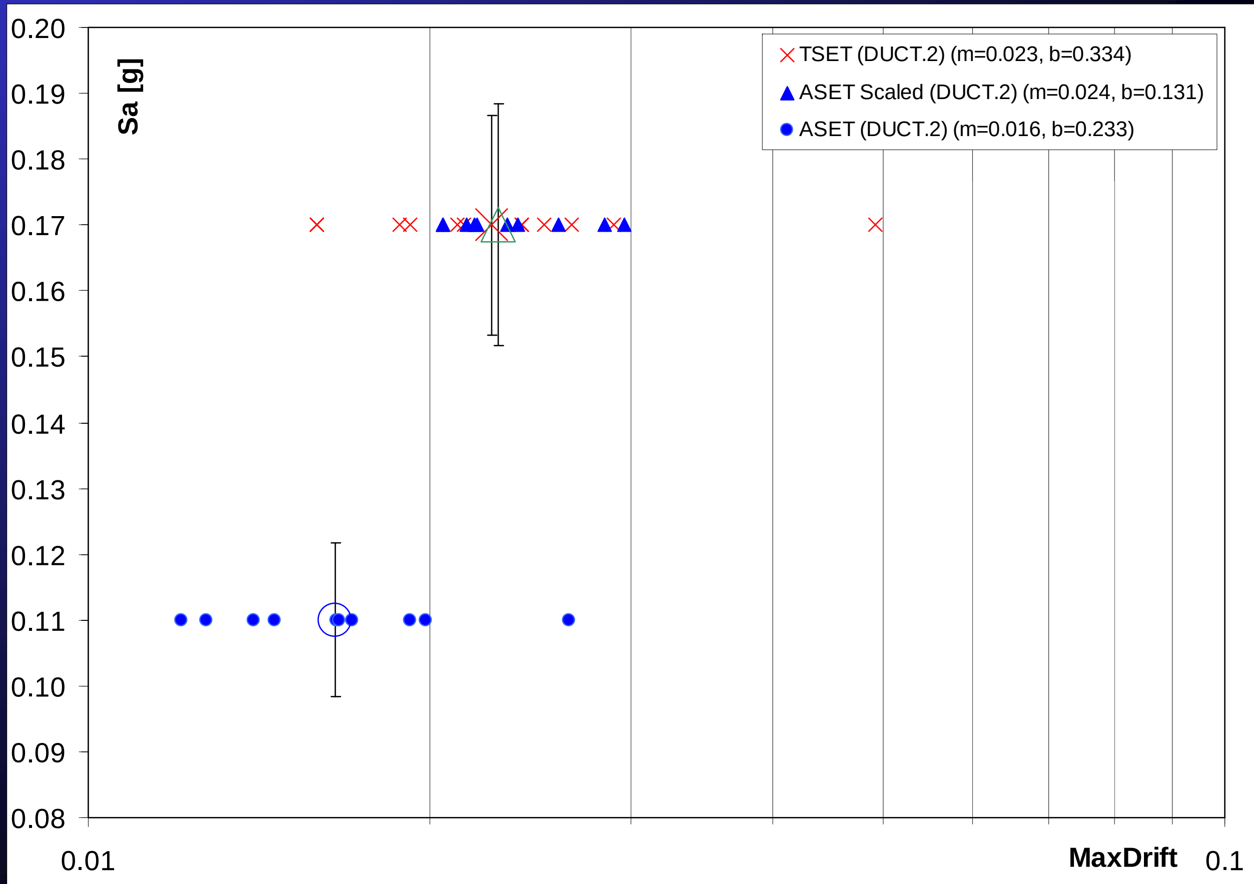
S_a



Drift

$\mu \approx 2$

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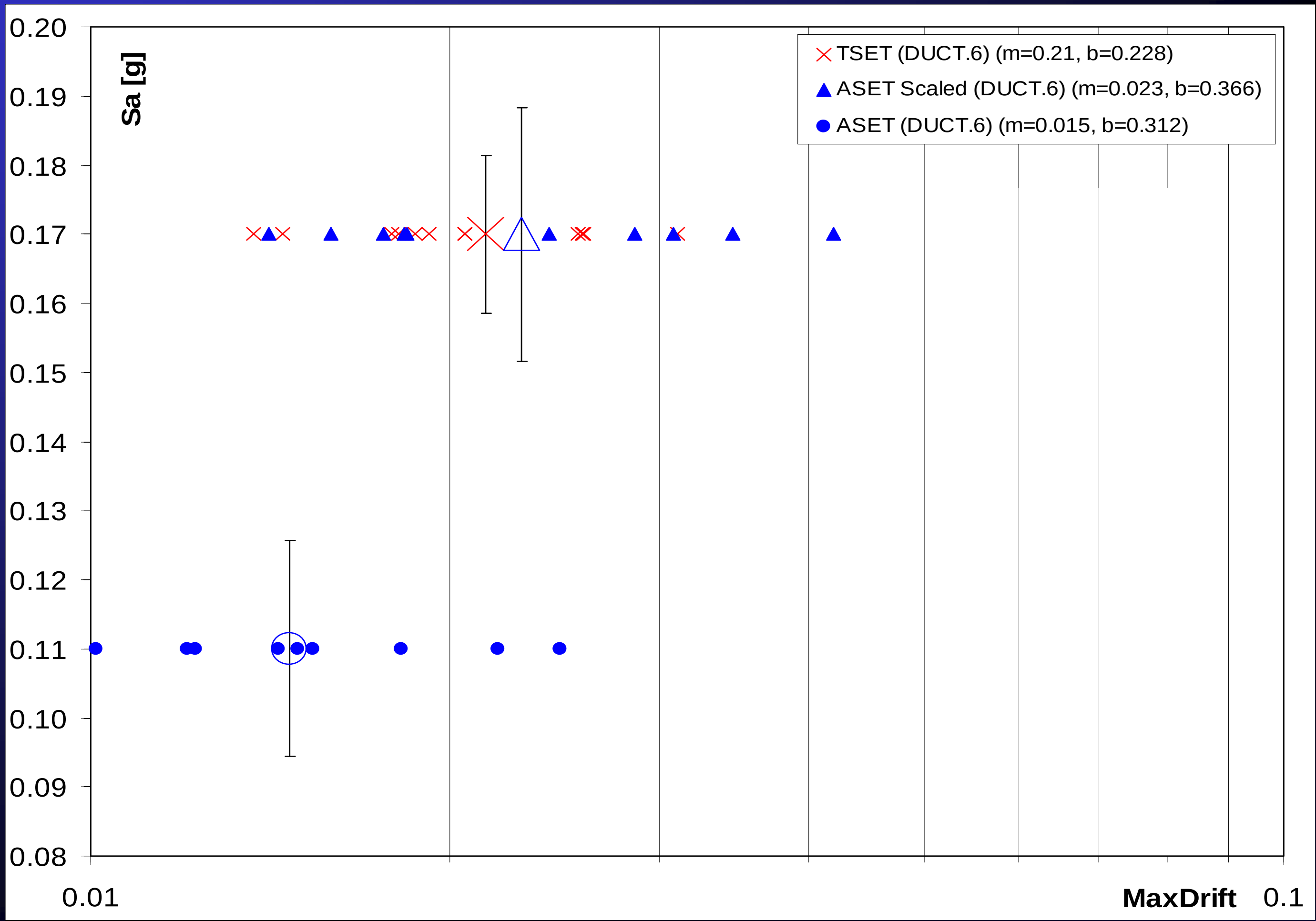
S_a



Drift

$\mu \approx 6$

Ductility ~6.5 Case; Fault Parallel Components

GROUP	Comment	Sample size	Median ratio	Estimation Beta (COV) of the ratio
A1		10	1.06	0.112
A2		10	1.27	0.170
A3	Case Just Looked at	10	1.13	0.136
A4		10	1.06	0.122
A5		10	1.09	0.131
A1+A2	Larger Sample Sizes	20	1.16	0.113
A3+A4		20	1.09	0.103
A5+A1		20	1.06	0.098
A1+A2+A3		30	1.15	0.099
A4+A5+A1		30	1.07	0.090

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2. Other Sets: Various sets taken to “stretch” the test of the hypothesis:

Strongest Records/ Weakest Records.

Individual Events

Most different magnitudes, etc.

Look at Ratio of: Test Set Median Drift to

Target Set (“Real”) Median Drift

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LOWEST TEN Sa	Recorded Strength	10	1.48	0.149
HIGHEST TEN Sa		10	0.96	0.106
CAPE MENDONCINO	Single Events	3	0.95	0.395
COALINGA		10	1.16	0.111
IMPERIAL VALLEY		10	1.29	0.144
LANDERS		6	1.07	0.115
LOMA PRIETA		8	1.12	0.182
NORTHRIDGE		7	0.88	0.116
LOW MAGNITUDE (6.3-6.4)	Low Magnitude	11	1.15	0.105
SOMMERVILLE'S SET 50/50	Test bed sets	10	1.25	0.133
SOMMERVILLE'S SET 10/50		10	1.38	0.140
SOMMERVILLE'S SET 02/50		10	1.02	0.117
SOIL TYPE C	Soil type	11	1.04	0.114
SOIL TYPE D		38	1.15	0.093

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Non-Linear SDOF Conclusion:

(Given scaling to common $S_a(T_1)$ level) median (displacement) EDPs are apparently effectively independent of the (non-extreme) record set used*.

Comments: Same conclusion found for transverse components. More periods and backbones and EDPs deserve testing to test the limits of applicability of this illustration.

*Provisos: Magnitudes not too low relative to general range of usual interest; no directivity or shallow, soft soil or basin edge issues.

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Non-Linear MDOF Building Study Bases:

DIRECT: Van Nuys (Transverse Frame); Same Scenario (M = 7; R = 20km); Target data set as above and one of the “ A (Random) Sets”.

RESULTS:

Target Records: median max. drift: 0.0056

Random Group 3: median max. drift: 0.0060

Ratio: 1.07 Beta of Ln (~COV) of Ratio 0.15

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<u>INDIRECT</u>: Starting from:

$$P[EDP > x] = \int\int\int ..P[EDP>x|IM,m,r,\ldots]\ f(IM|m,r\ldots)\ |d\lambda(m, r, \ldots)|\ dm\ dr\ldots$$

We can simplify to:

$$P[EDP > x] = \int P[EDP>x|IM]\ |d\ \lambda(IM)|$$

<u>if</u> there is conditional independence ("sufficiency"), i.e., if

$$P[EDP>x|IM,m,r,..] = P[EDP>x|IM] \text{ for all } m, r..$$

Consider: Van Nuys (Baker, 2003) and then two extreme cases. (Jalayer, 2003). Note: <u>No</u> scaling to median (stripe).

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(Conditional) Independence check: Observe residuals of a Drift on Sa regression vs. residuals of a Magnitude on Sa regression. Any apparent dependence?

First-order (median) Linear Dependence Test: Is the slope of Drift residuals vs. Magnitude residuals regression statistically significantly different from zero?
If so is it "importantly" different from zero?

Why only magnitude here?

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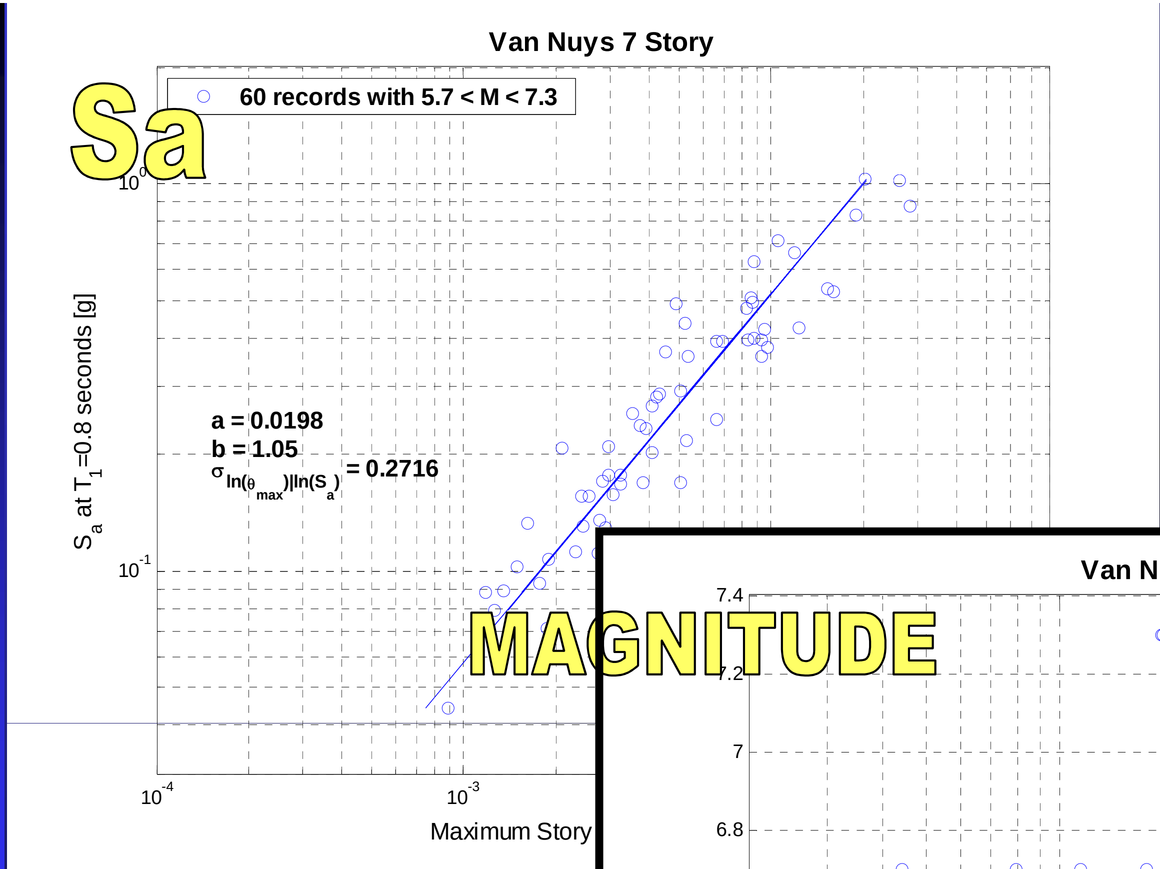

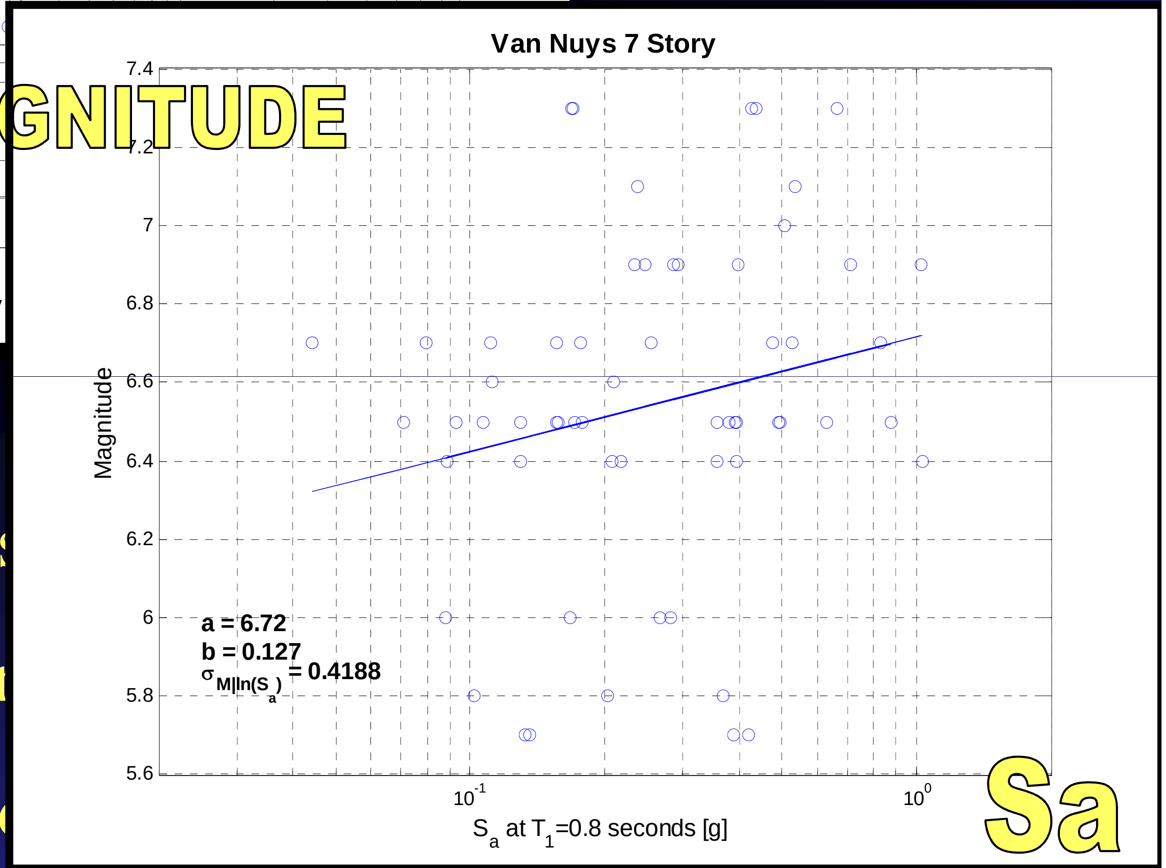

Van Nuys Trans

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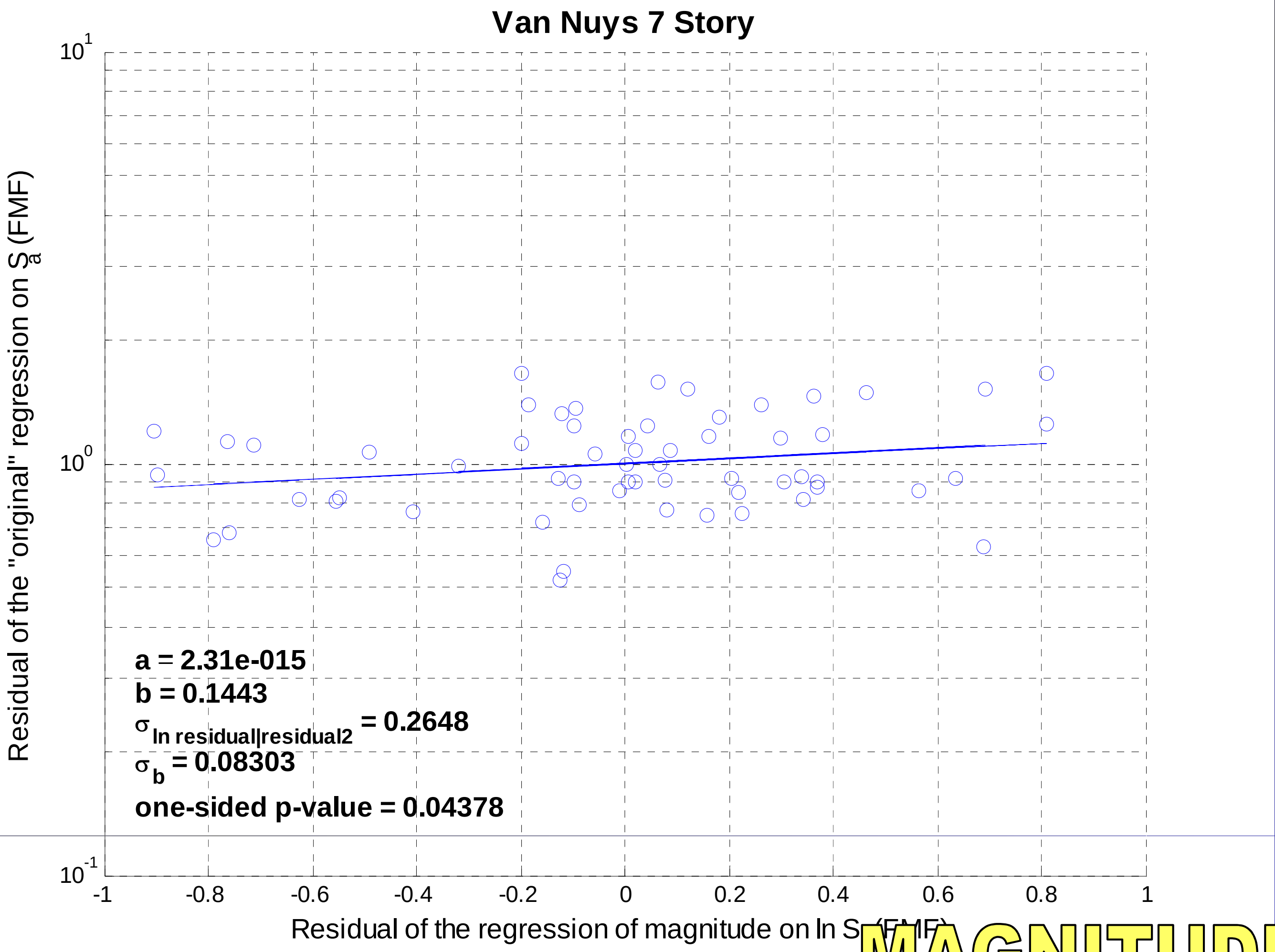
DRIFT



Residual-residual plot: drift versus magnitude (given S_a) for Van Nuys. (Ductility range: 0.3 to 6) (60 PEER records, as recorded.)

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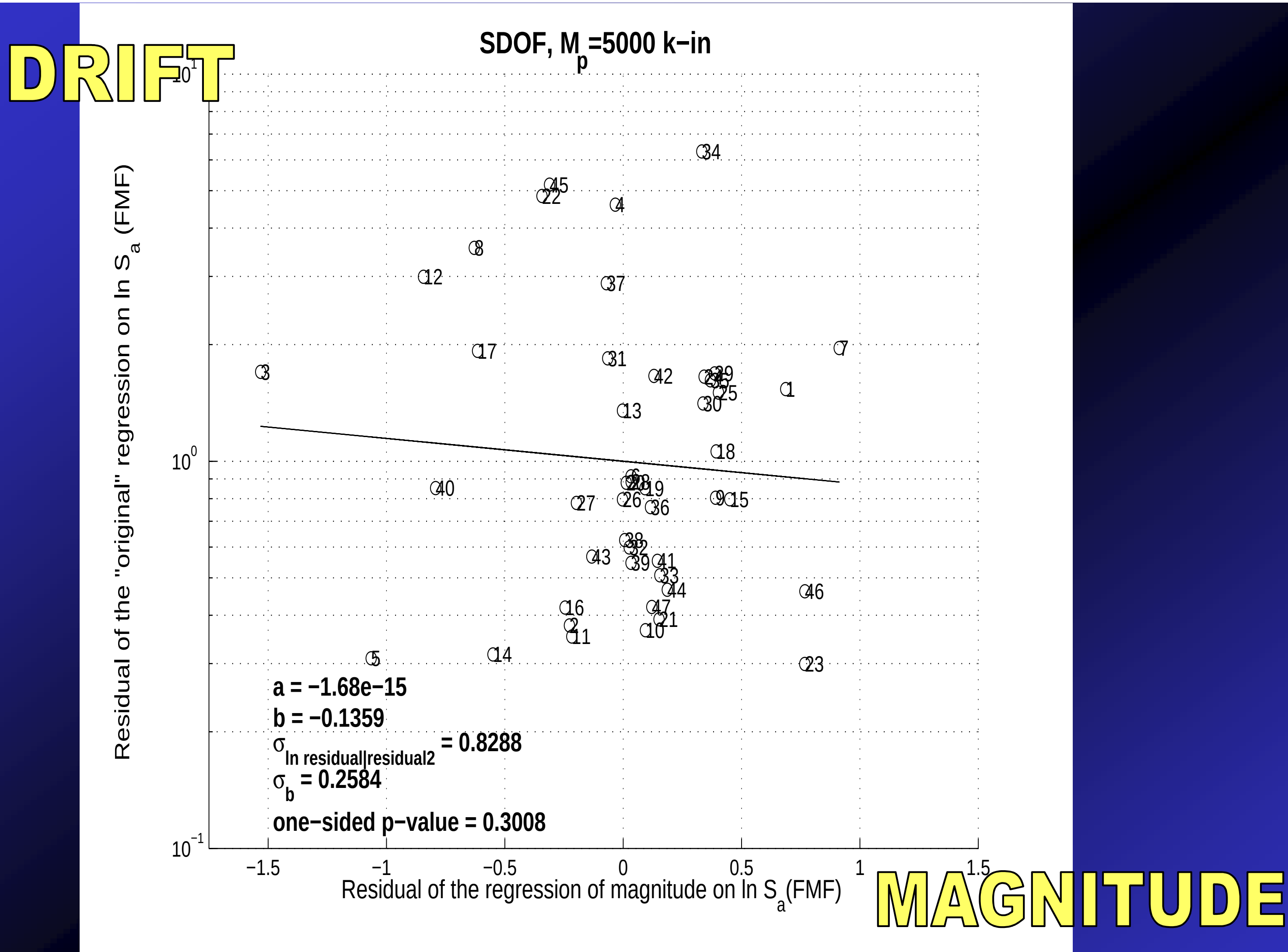

Residual-residual plot: drift versus magnitude (given S_a) of a very short period (0.1 sec) SDOF bilinear system. (Ductility range 1 to 20.) (47 PEER records, as recorded.)

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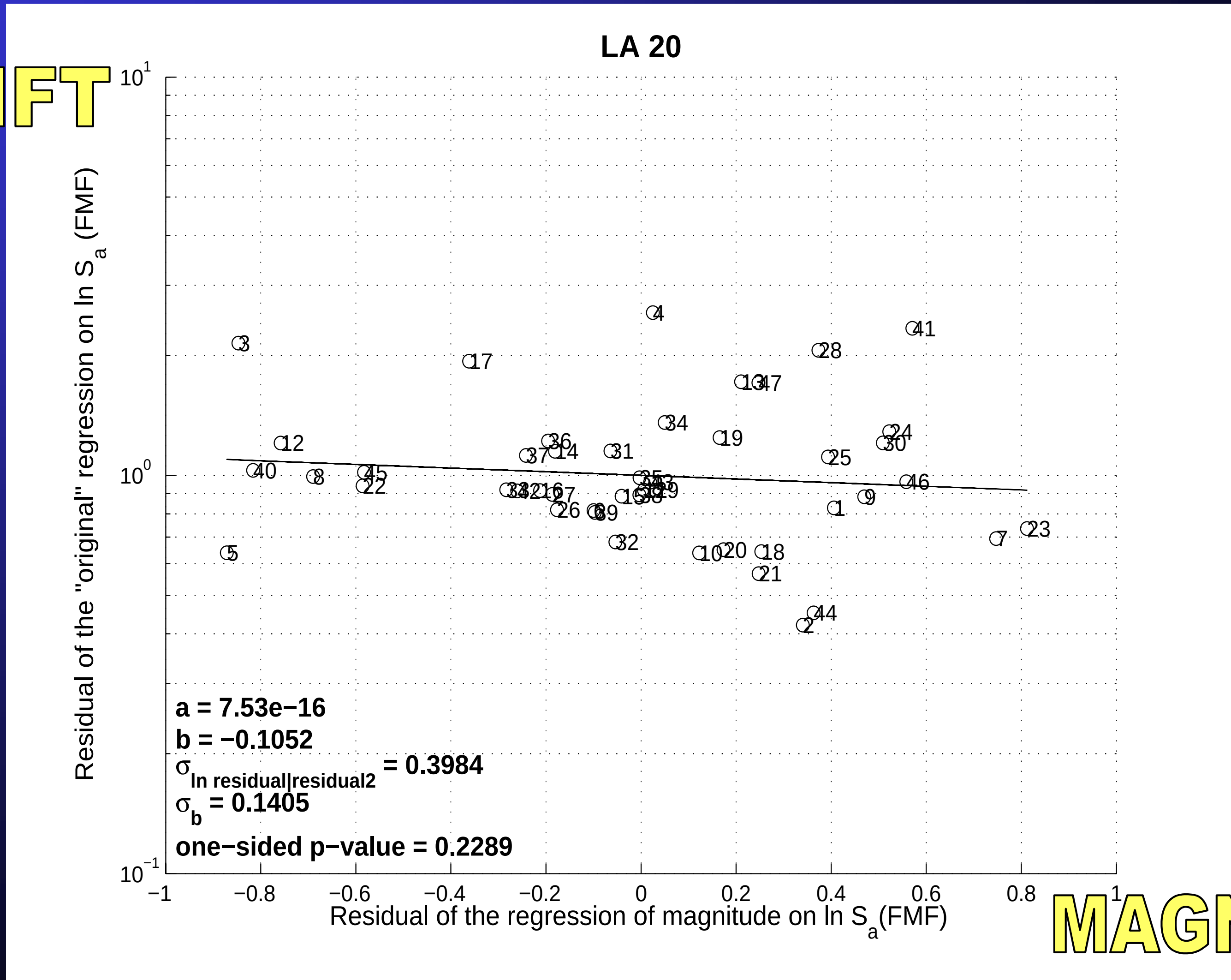
DRIFT



MAGNITUDE

Residual-residual plot: drift versus magnitude (given S_a) for <u>4-second, fracturing-connection model of SAC LA20</u>. Ductility range: 0.2 to 1.5. Same records.

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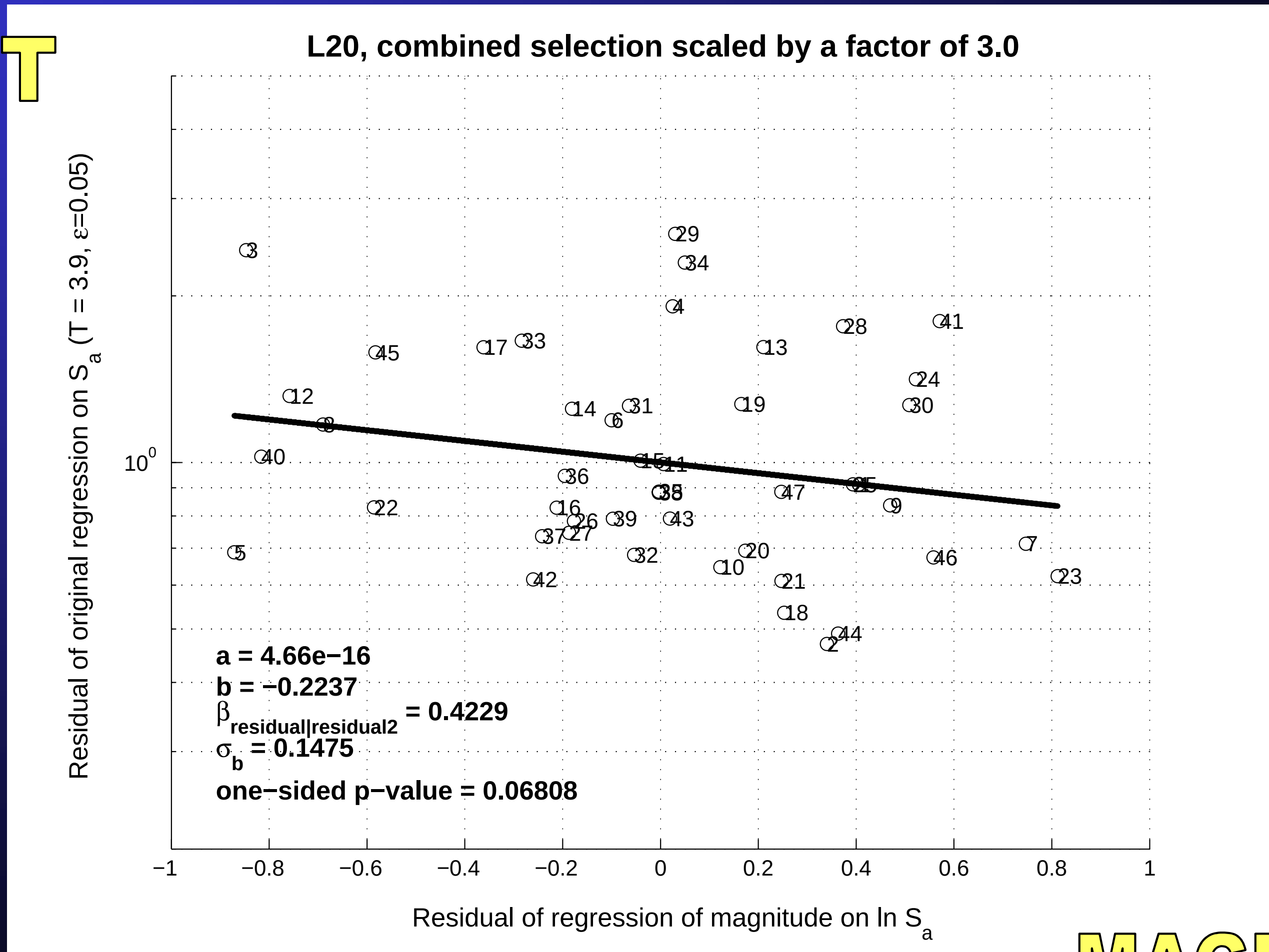
DRIFT



MAGNITUDE

Residual-residual plot: drift versus magnitude (given S_a) for 4-second, fracturing-connection model of SAC LA20. Records scaled by 3. <u>Ductility range: mostly 0.5 to 5</u>

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Non-Linear MDOF Conclusion:

(Given $S_a(T_1)$ level) the median (displacement) EDP is apparently independent of event parameters such as M, R, …*.

Implication: the record set used need not be selected carefully to match these parameters to those relevant to the site and structure.

Comments: More periods and backbones and EDPs deserve testing to test the limits of applicability of this illustration. Consistent with Ricardo Medina findings.

*Provisos: Magnitudes not too low relative to general range of usual interest; no directivity or shallow, soft soil or basin edge issues.

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Directivity Impacted Sites and Structures:

Some options:

1. Add additional parameters (e.g., x Cos θ) to M, R, …..
Check as here.

2. Improve the IM to make it sufficient with respect to these parameters too. (Candidates: Cordova, Luco, …)

3. Use vector valued IM such that the vector is sufficient.

4. Introduce (disagg-based) weighted regression to "correct" for non-representative sample (e.g., Shome, Bazzurro, Jalayer).