Summary of SCEC Broadband Platform Finite Fault Simulations:

to develop Mw scaling relationships of FAS,
for use in the empirical FAS model

NGA-E SSHAC Workshop 3A

Thursday, October 30

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Background

- A conclusion of the NGA-East SSHAC workshop in July was that the finite fault simulations as implemented on the SCEC Broadband Platform (SCEC BBP) were not mature enough to use for predicting the absolute values of ground motions. The recommendation was that only relative values be used, i.e. the scaling behavior.

- As a result, we have performed simulations with the latest version of the BBP for a set of forward scenarios in order to assess how the simulations scale with magnitude in FAS and PSA space; and to extrapolate to large M.

- The results of these simulations are implemented in the empirical FAS model (next talk by J. Hollenback). The scaling in PSA will also be shared with other GMPE developers.

SCEC Broadband Platform

- BBP version “14.10” including the most recent updates for the EUS.
- 4 simulation methods:

Method	Nickname	Contact Persons
Graves & Pitarka	GP	Rob Graves & Arben Pitarka
San Diego State University	SD	Kim Olsen & Rumi Takedatsu
Ex-Sim	EX	Karen Assatourians & Gail Atkinson
UC Santa Barbara	SB	Ralph Archuleta & Jorge Crempien

- Velocity model for all simulations:
  - Mineral, Virginia (top velocity = 1 km/s)
- 16 source realizations of each scenario:
  - Random hypocenter placement (but away from fault plane edges)

Scenario Events

- Style of Faulting:
  - Reverse only (strike = 0°; dip = 45°; average rake = 90°)
- Magnitudes:
  - **M** = 5.0, 5.5, 6.5, 7.5, 8.0
- Depth to top of rupture plane (Ztor)
  - Ztor = 0, 5, 10 km
  - Exception: Ztor = 0, 5 km for the M 8.0 case
- Fault Dimensions
  - Determined with the Stable Continent Region (SCR) relations of Leonard (2010)

Magnitude	Length (km)	Width (km)	Area (km^2)
5.0	2.5 (2.55)	2.5 (2.58)	6.25 (6.46)
5.5	5 (5.08)	4 (4.02)	20 (20.4)
6.5	20 (20.2)	10 (10.1)	200 (204)
7.5	80 (80.2)	25 (25.4)	2000 (2041)
8.0	160 (159.8)	40 (40.4)	6400 (6456.5)

Summary of Scenario Events

M	Strike	Rake	Dip	Ztor (km)	L (km)	W (km)
5.0	0	90	45	0	2.5	2.5
5.5	0	90	45	0	5.0	4.0
6.5	0	90	45	0	20.0	10.0
7.5	0	90	45	0	80.0	25.0
8.0	0	90	45	0	160.0	40.0
5.0	0	90	45	5	2.5	2.5
5.5	0	90	45	5	5.0	4.0
6.5	0	90	45	5	20.0	10.0
7.5	0	90	45	5	80.0	25.0
8.0	0	90	45	5	160.0	40.0
5.0	0	90	45	10	2.5	2.5
5.5	0	90	45	10	5.0	4.0
6.5	0	90	45	10	20.0	10.0
7.5	0	90	45	10	80.0	25.0

Station Setup

- For each scenario, stations are located in constant Rrup "rings"
  - All stations are on the foot wall
  - A total of 10 stations on each ring, equally spaced

- 12 Rrup rings at: 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 km
  - Exception: no Rrup = 5 km ring for the Ztor = 10 km scenarios.

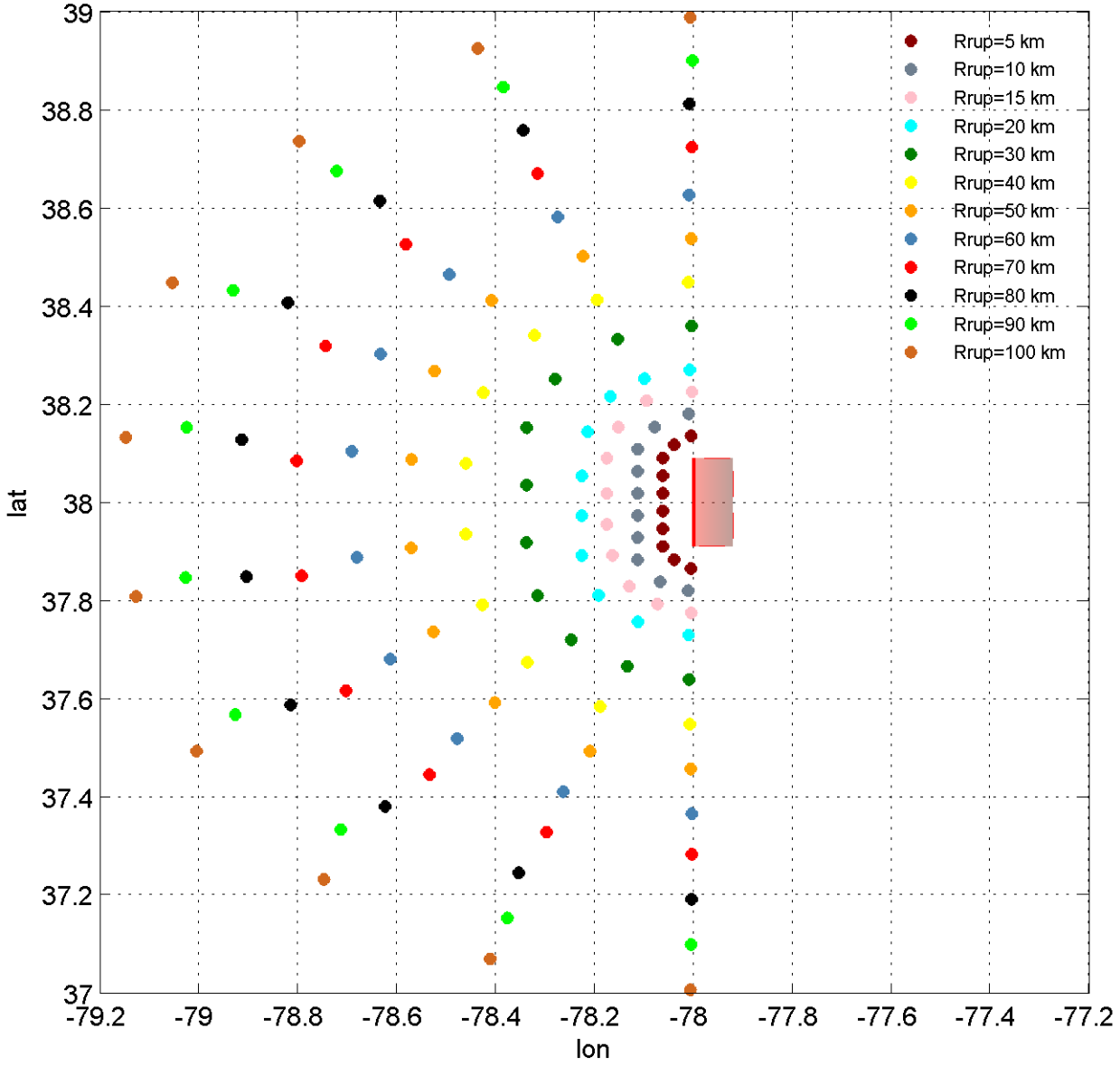
Aside:
- 120 stations per scenario
- 14 scenarios
- 16 hypocenter realizations of each scenario
- 4 simulations methods
- 2 horizontal components

~ 210,000 simulated time series

Station Setup

Example 1

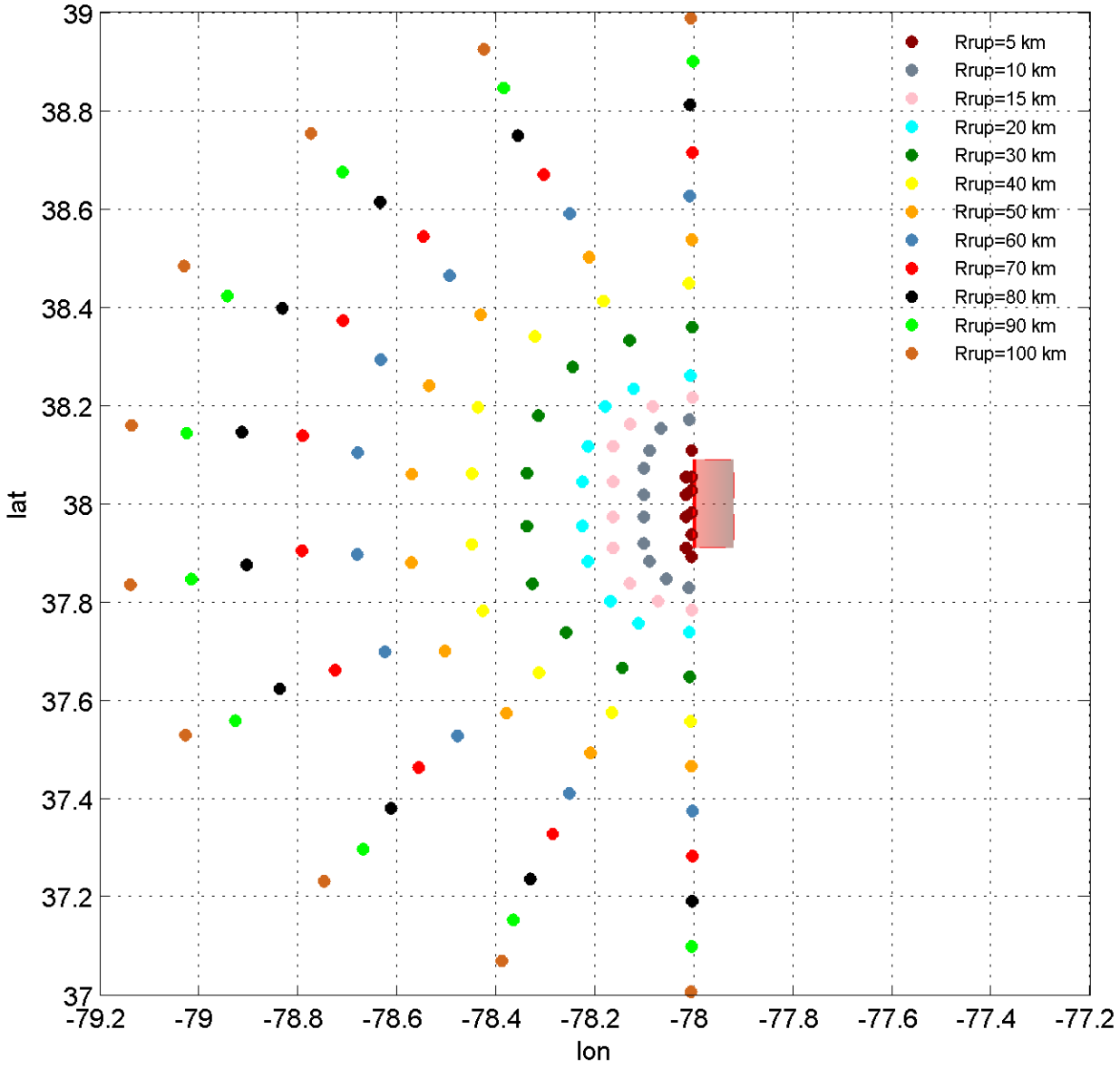
Reverse
M 6.5
Ztor = 0 km



Station Setup

Example 2

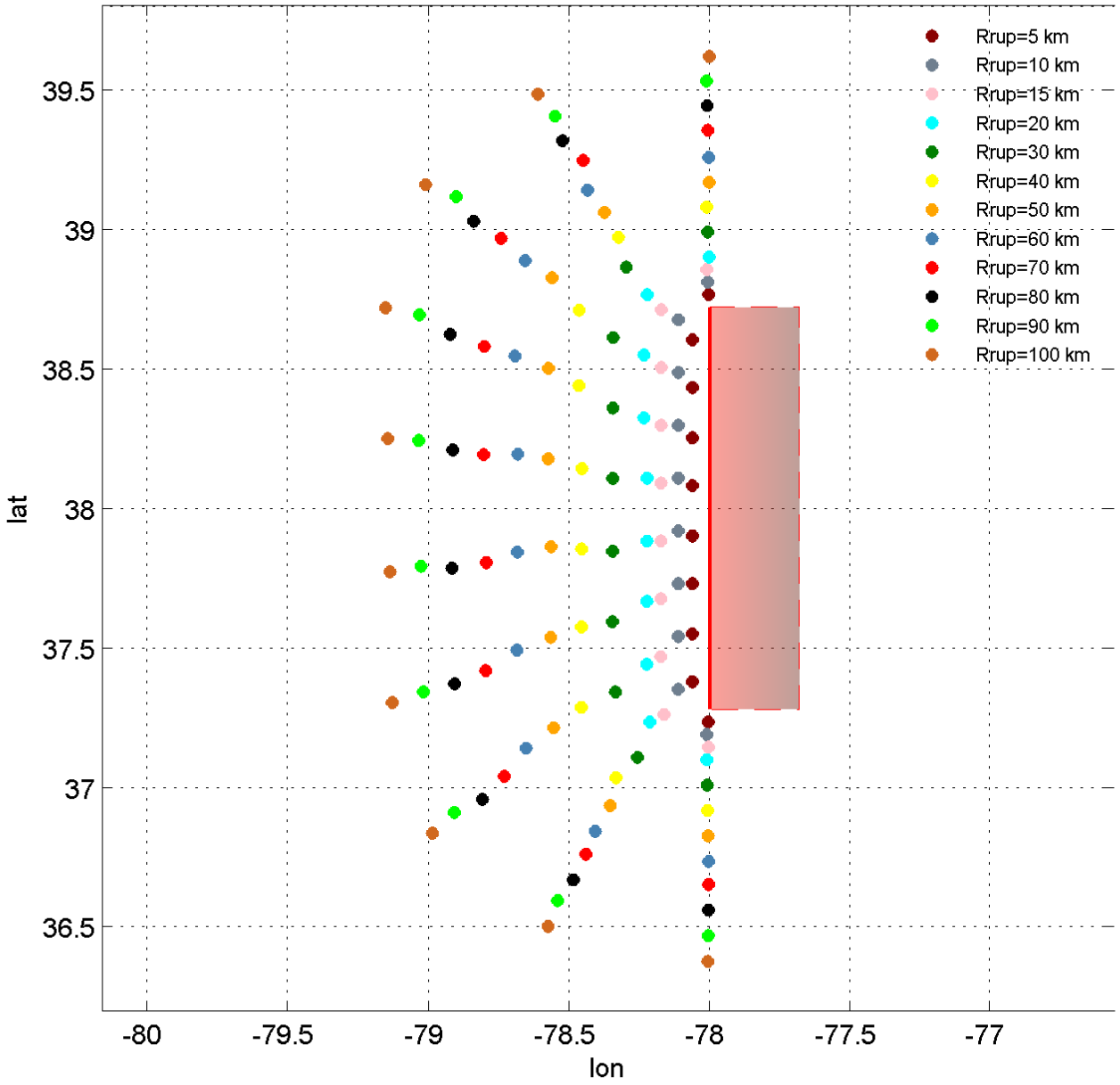
Reverse
M 6.5
Ztor = 5 km



Station Setup

Example 3

Reverse
M 8.0
Ztor = 0 km



Processing of Results

1. Compute the FAS of each simulated time series
   - Calculated using Dave Boore's package TSPP_v4.8

<u>For a given Ztor and simulation method:</u>

2. Average (geometric mean) of FAS at each station over 16 realizations
   - Call this **"FAS_i"** for i=1:10 stations

3. Average (geometric mean) of FAS_i at each Rrup band (j)
   - Call this ***"FAS_j"*** for j=1:12 Rrup distances
   - Rrup = 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100 km

4. Smooth ***FASj*** using Konno & Ohmachi (1998)
   - Smoothing parameter b=30

5. Repeat for Magnitudes 5.0, 5.5, 6.5, 7.5, 8.0

6. Calculate FAS Ratios and PSA Ratios *relative to M 5.0 scenario*

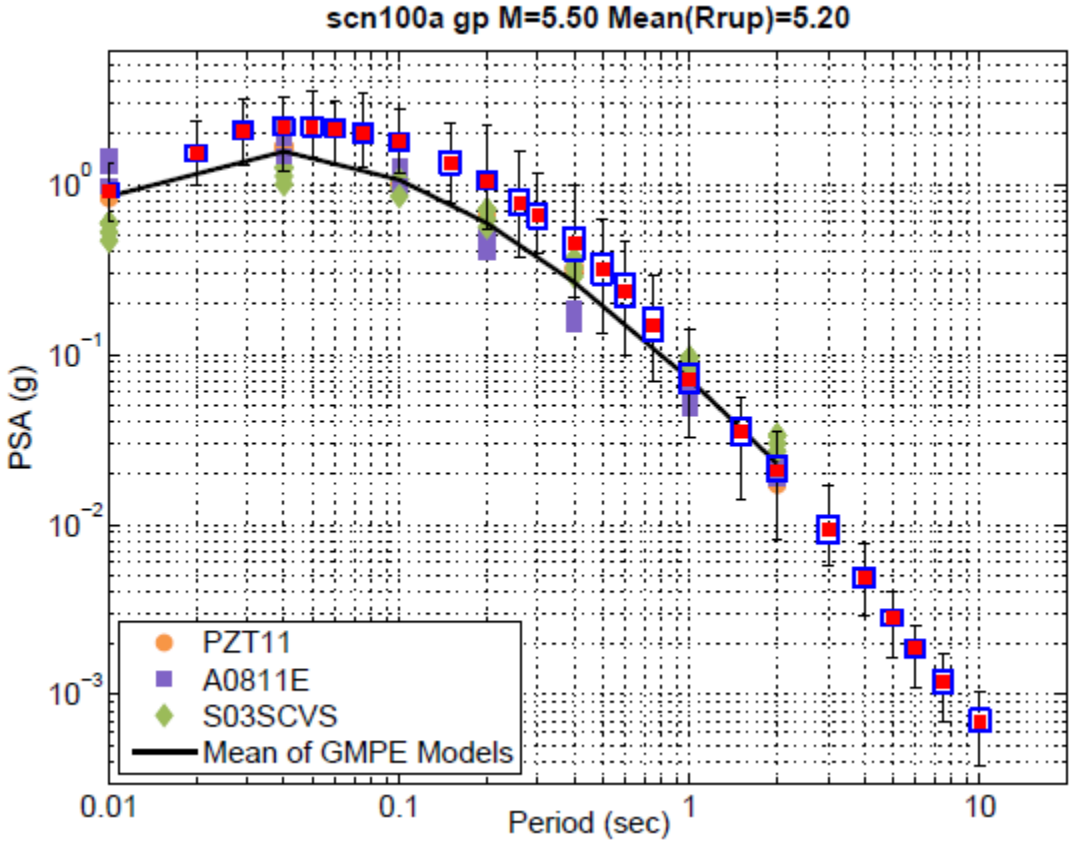
<u>Repeat 2-6 for each Ztor case and each simulation method</u>

Products

1. RotD50 spectra for each Rrup ring, plotted with GMPES

Products

1. **RotD50 spectra for each Rrup ring, plotted with GMPES**
   - A0811E = Atkinson 2008-2011 EPRI
   - PZT11 = Pezeshk et al. 2011 model
   - S03SCVS = Silva et al. 2003 Single Corner Variable Stress Model



The bar plots show the mean (red square) and the standard deviation (blue box) of the simulations, while error bars show the extrema for all 16 source realizations. A similar set of figures are created for each Rrup band, for each scenario.

Products

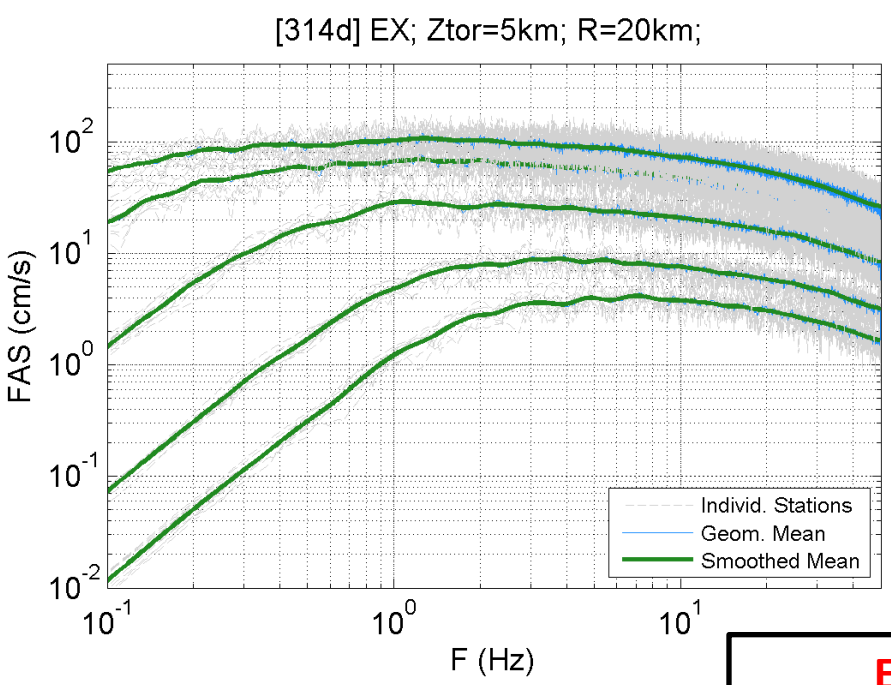
1. RotD50 spectra for each Rrup ring, plotted with GMPES

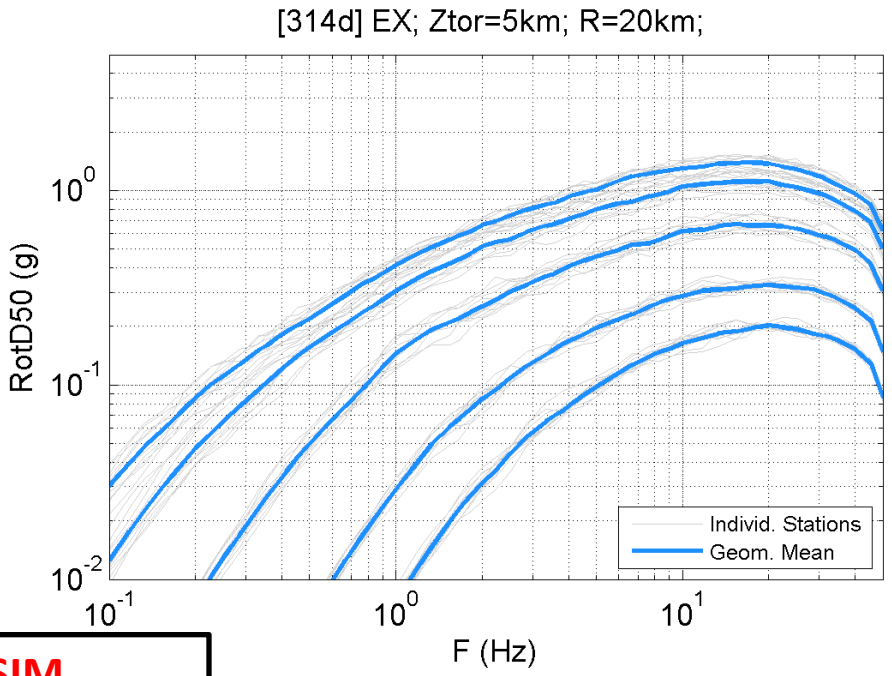
2. **FAS and RotD50 of individual stations; also averaged and smoothed**

3. **FAS and PSA Ratios relative to M 5.0 case**
   - **FAS Ratio vs. Frequency**

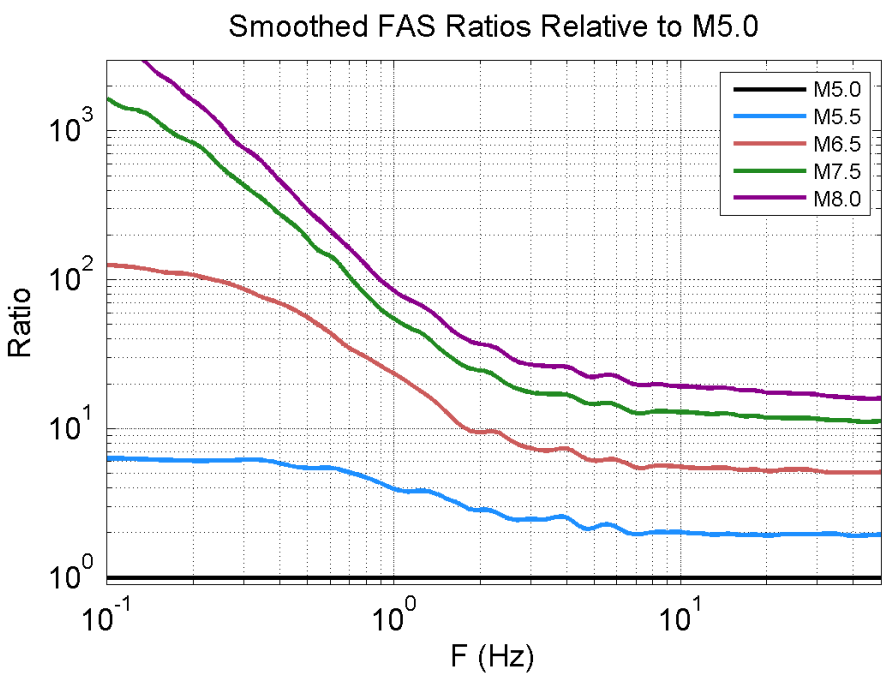
The results presented here are for:

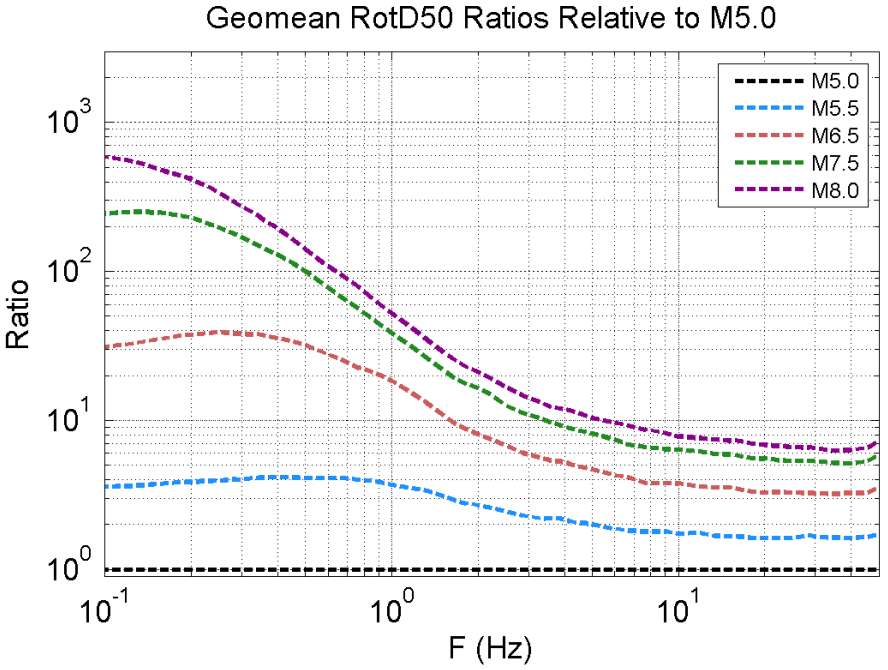
- Ztor = 5 km
- Rrup = 20 km
- Varying Magnitude and frequency

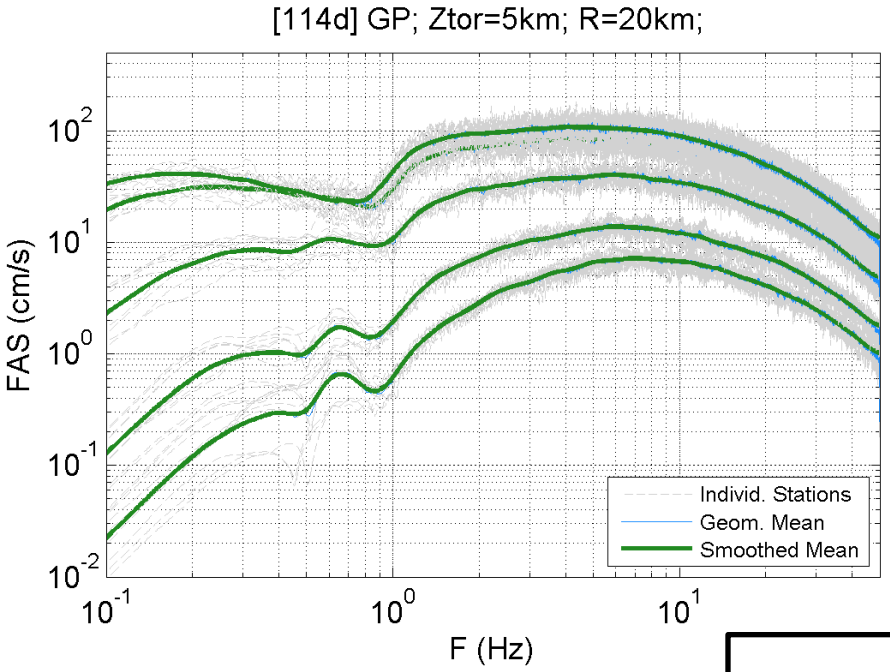

[314d] EX; Ztor=5km; R=20km;
FAS (cm/s)
F (Hz)
Individ. Stations
Geom. Mean
Smoothed Mean

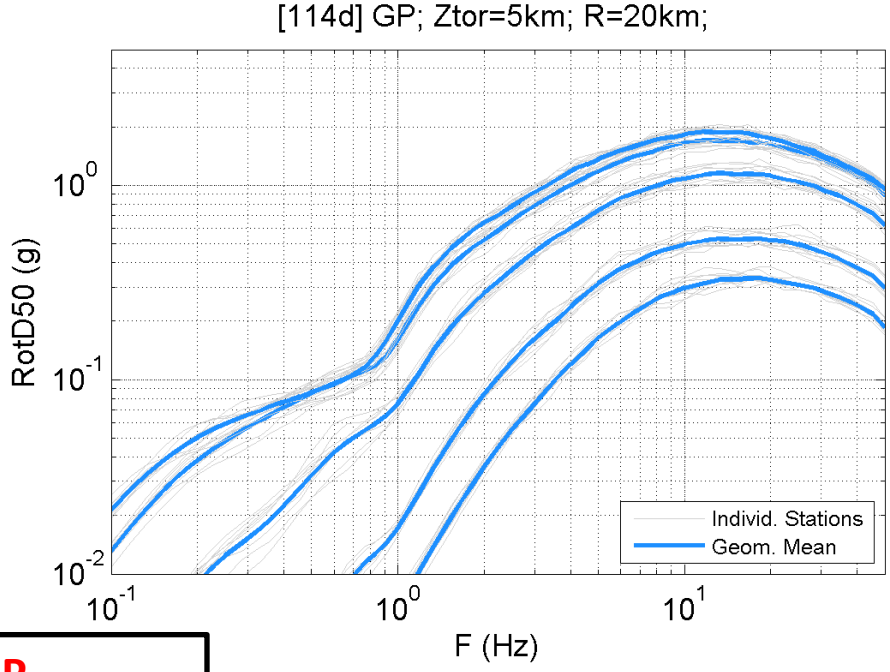

[314d] EX; Ztor=5km; R=20km;
RotD50 (g)
F (Hz)
Individ. Stations
Geom. Mean

EXSIM

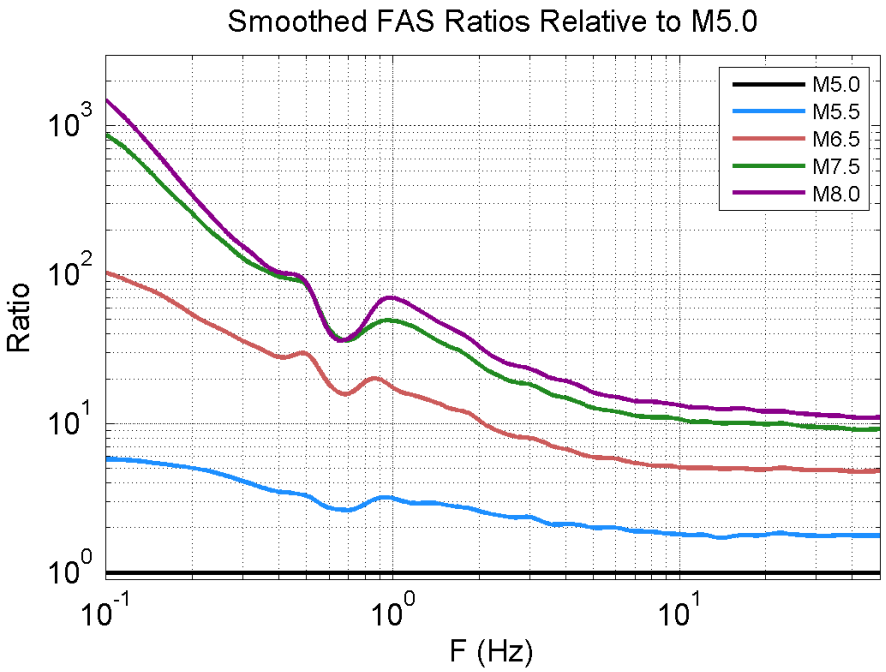

Smoothed FAS Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0

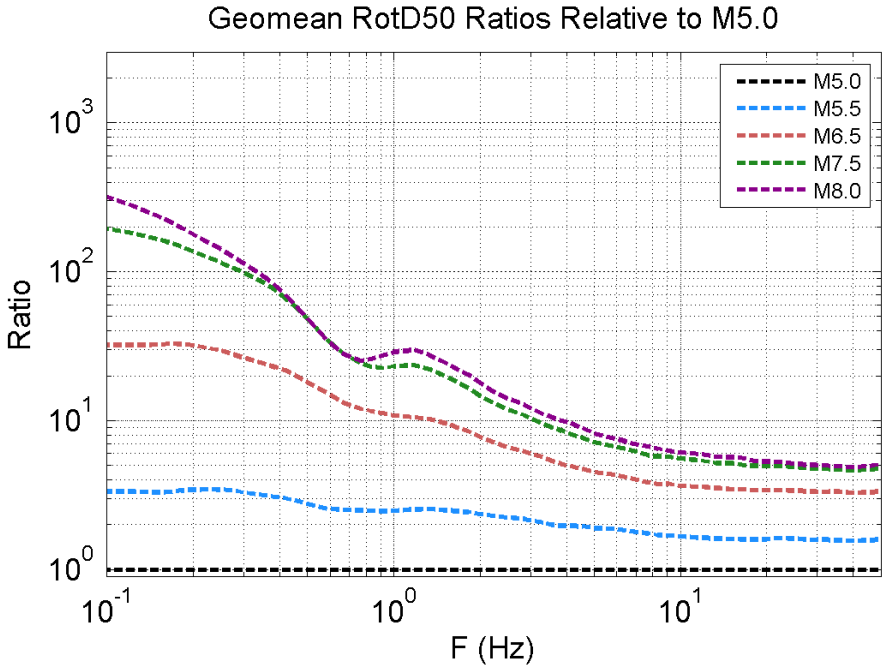

Geomean RotD50 Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0

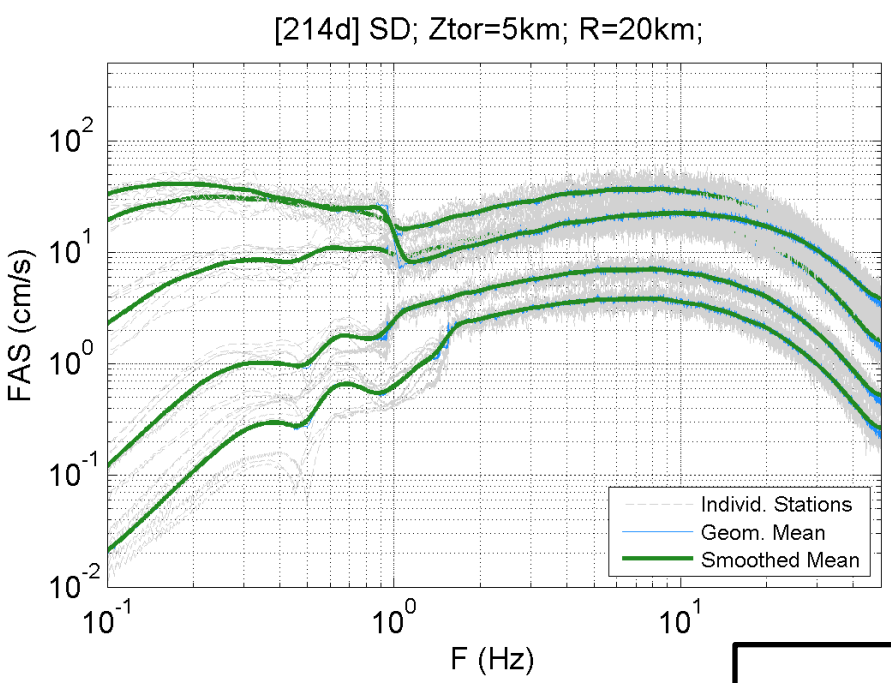

[114d] GP; Ztor=5km; R=20km;
FAS (cm/s)
F (Hz)
Individ. Stations
Geom. Mean
Smoothed Mean

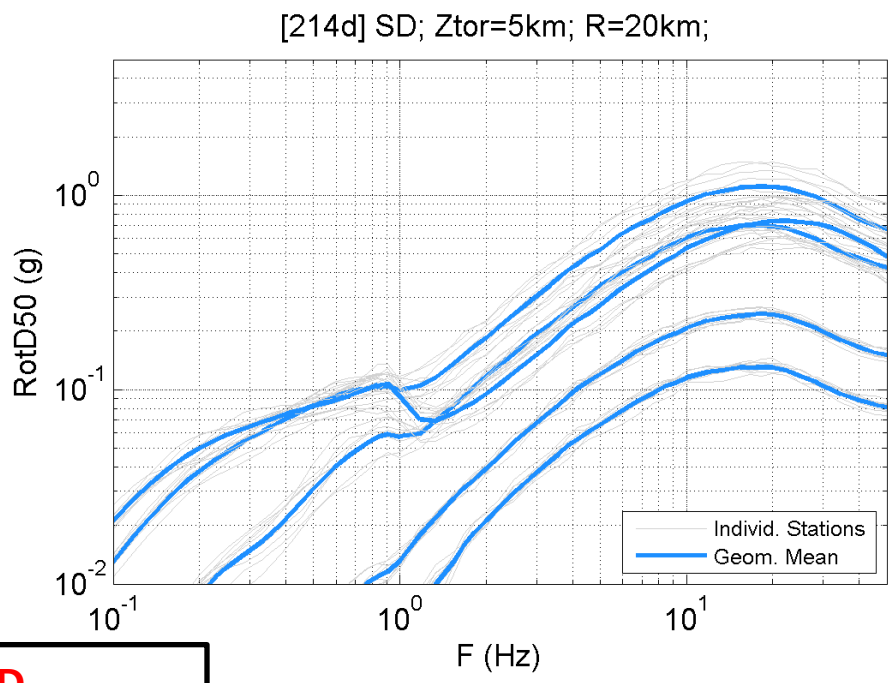

[114d] GP; Ztor=5km; R=20km;
RotD50 (g)
F (Hz)
Individ. Stations
Geom. Mean

GP

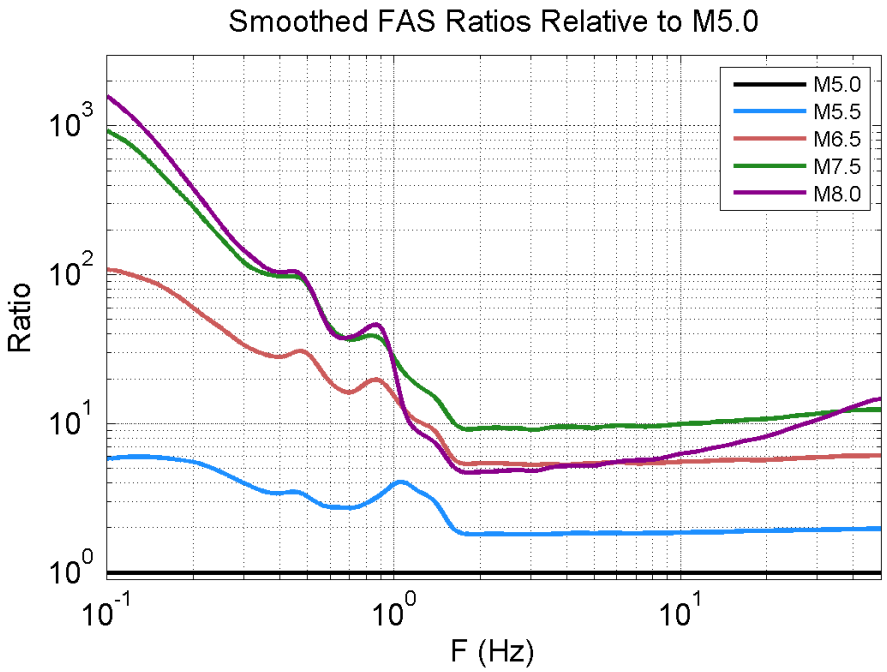

Smoothed FAS Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0

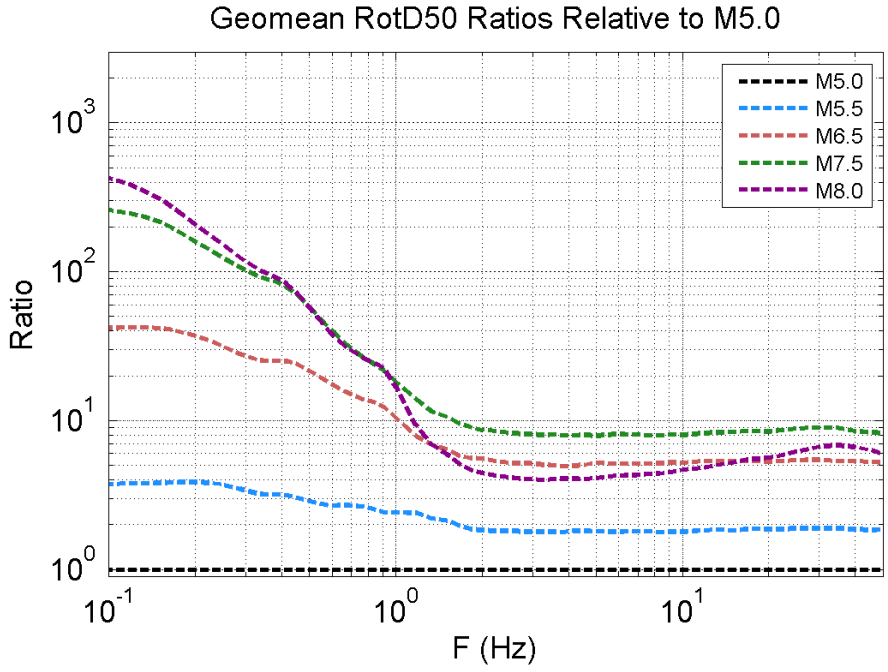

Geomean RotD50 Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0

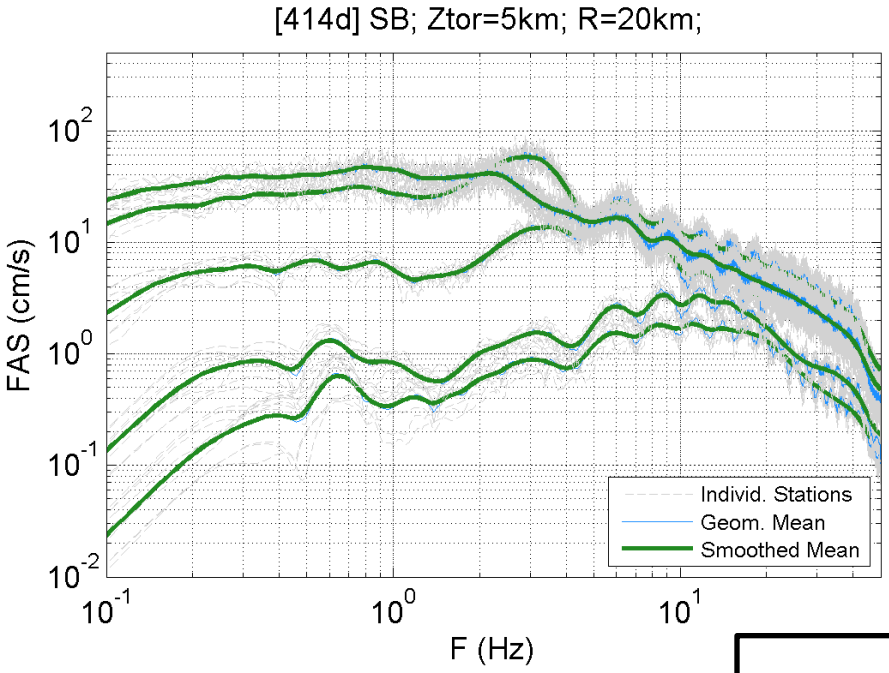

[214d] SD; Ztor=5km; R=20km;
FAS (cm/s)
F (Hz)
Individ. Stations
Geom. Mean
Smoothed Mean

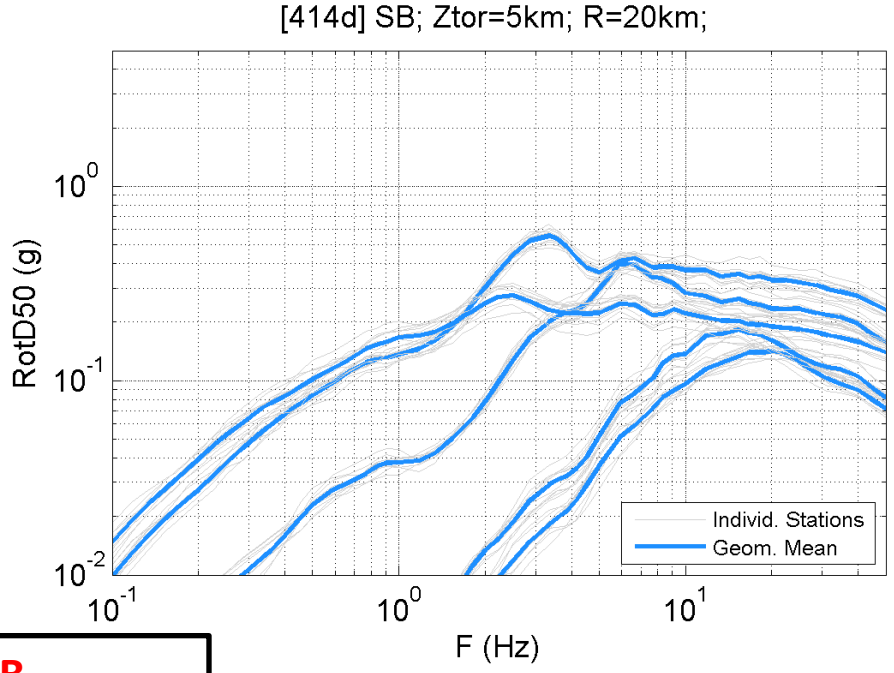

[214d] SD; Ztor=5km; R=20km;
RotD50 (g)
F (Hz)
Individ. Stations
Geom. Mean

SD

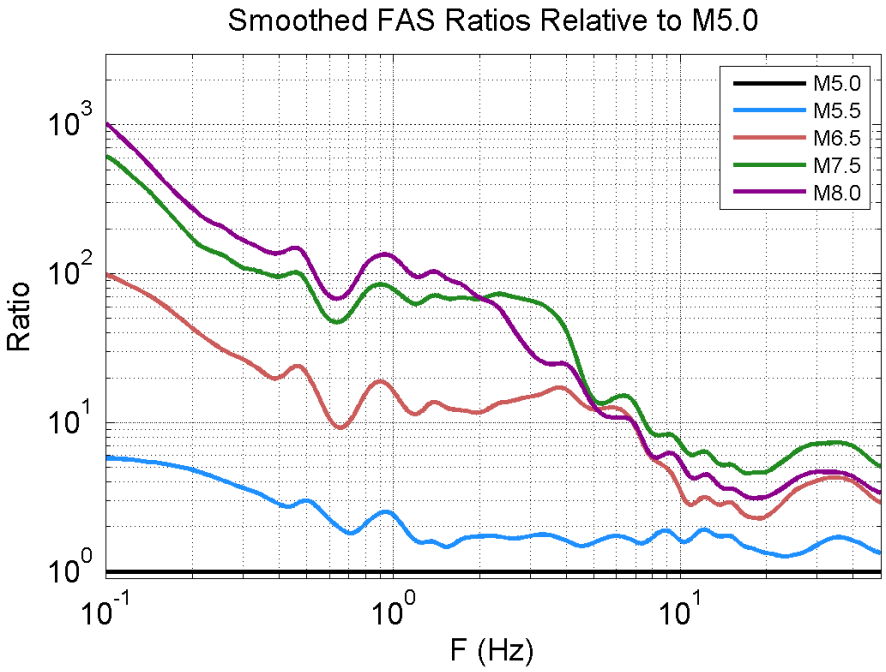

Smoothed FAS Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0

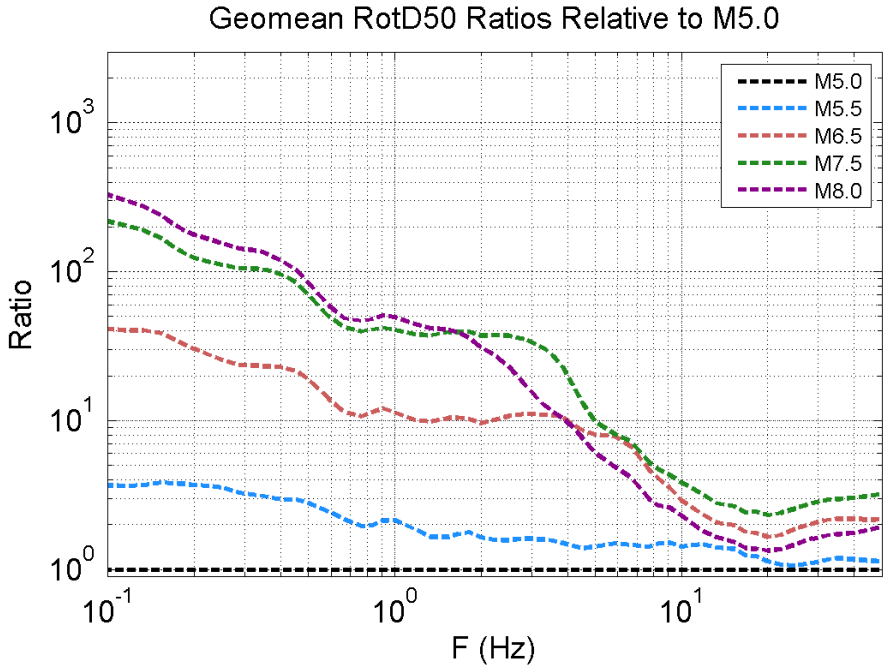

Geomean RotD50 Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0


[414d] SB; Ztor=5km; R=20km;
FAS (cm/s)
F (Hz)
Individ. Stations
Geom. Mean
Smoothed Mean


[414d] SB; Ztor=5km; R=20km;
RotD50 (g)
F (Hz)
Individ. Stations
Geom. Mean

SB

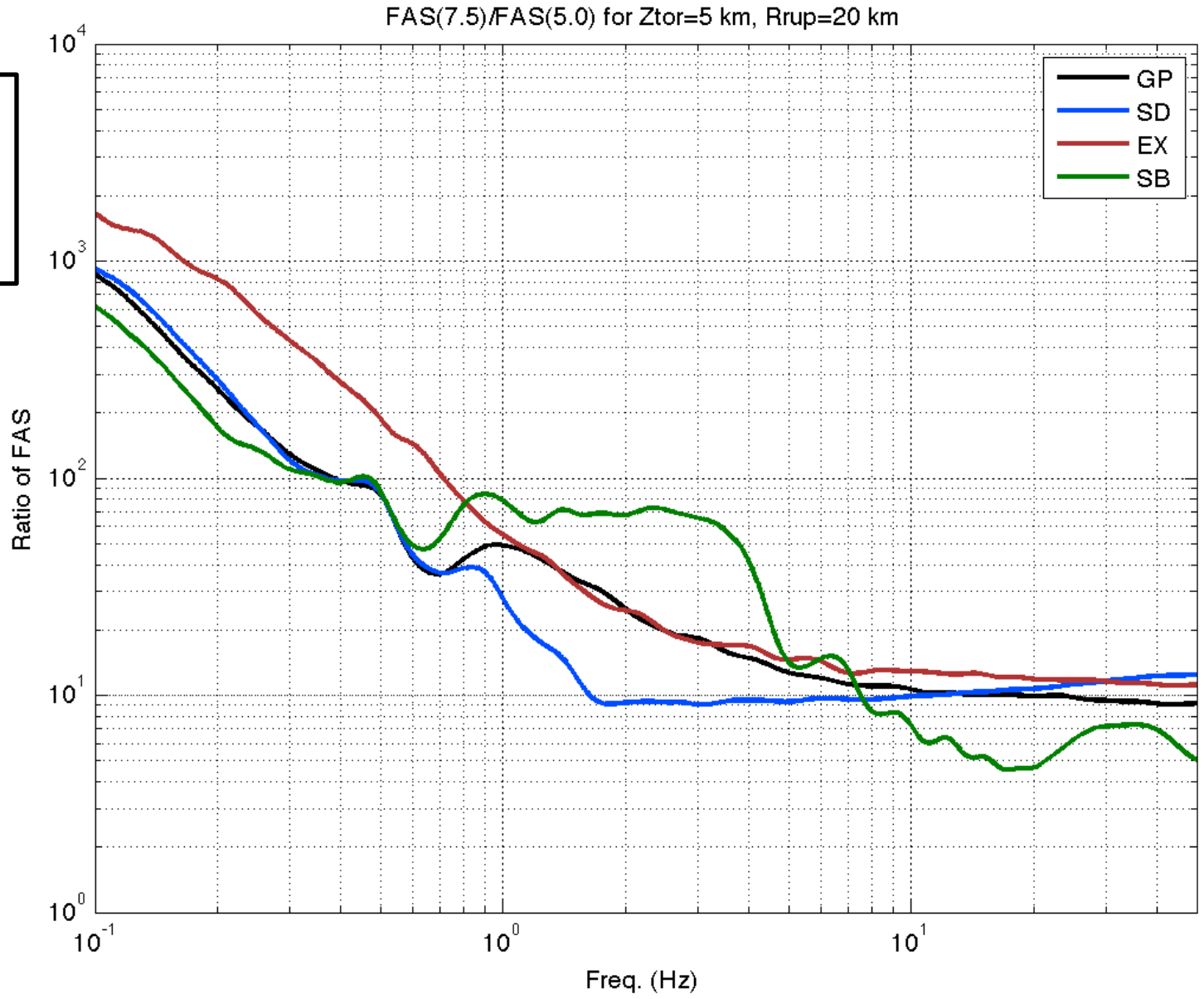

Smoothed FAS Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0


Geomean RotD50 Ratios Relative to M5.0
Ratio
F (Hz)
M5.0
M5.5
M6.5
M7.5
M8.0

FAS Ratio vs. Freq (4 Methods)

M 7.5

Ztor = 5 km
Rrup = 20 km



Products

1. RotD50 spectra for each Rrup ring, plotted with GMPES

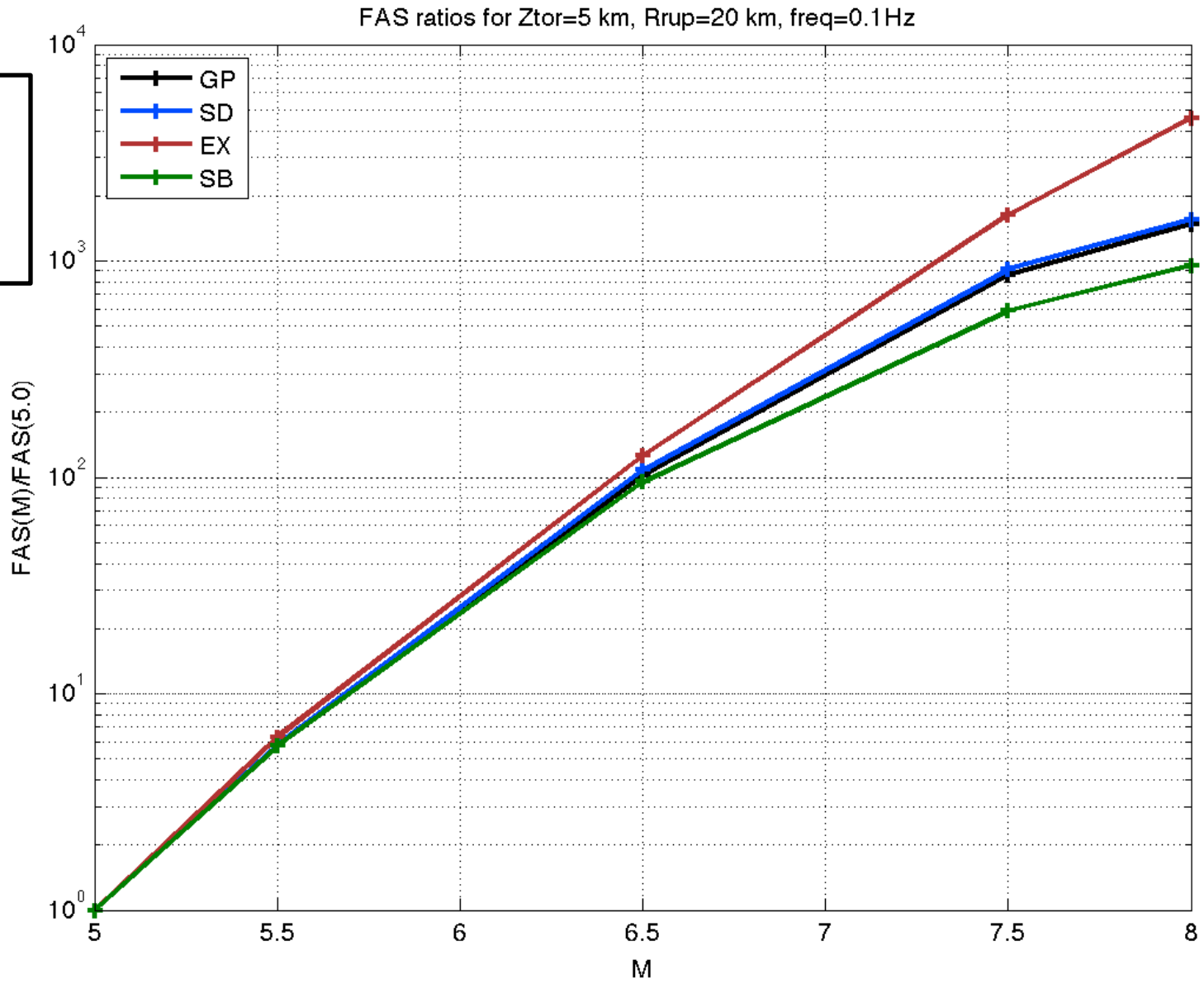
2. FAS and RotD50 of individual stations; also averaged and smoothed

3. FAS Ratios relative to M 5.0 case
   - FAS Ratio vs. Frequency
   - **FAS Ratio vs. M**

FAS Ratio vs. M (4 Methods)

F = 0.1 Hz

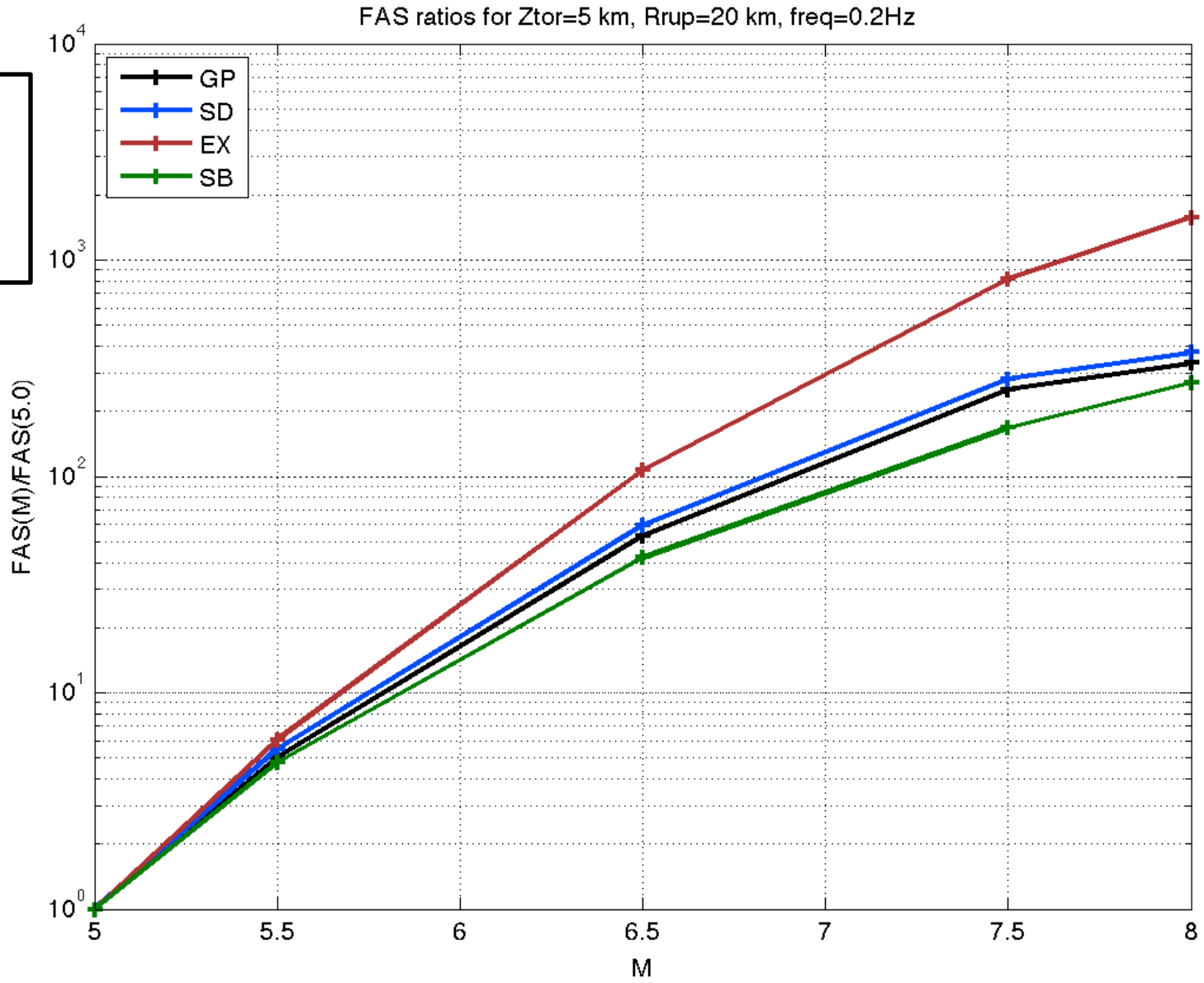
Ztor = 5 km
Rrup = 20 km



FAS Ratio vs. M (4 Methods)

F = 0.2 Hz

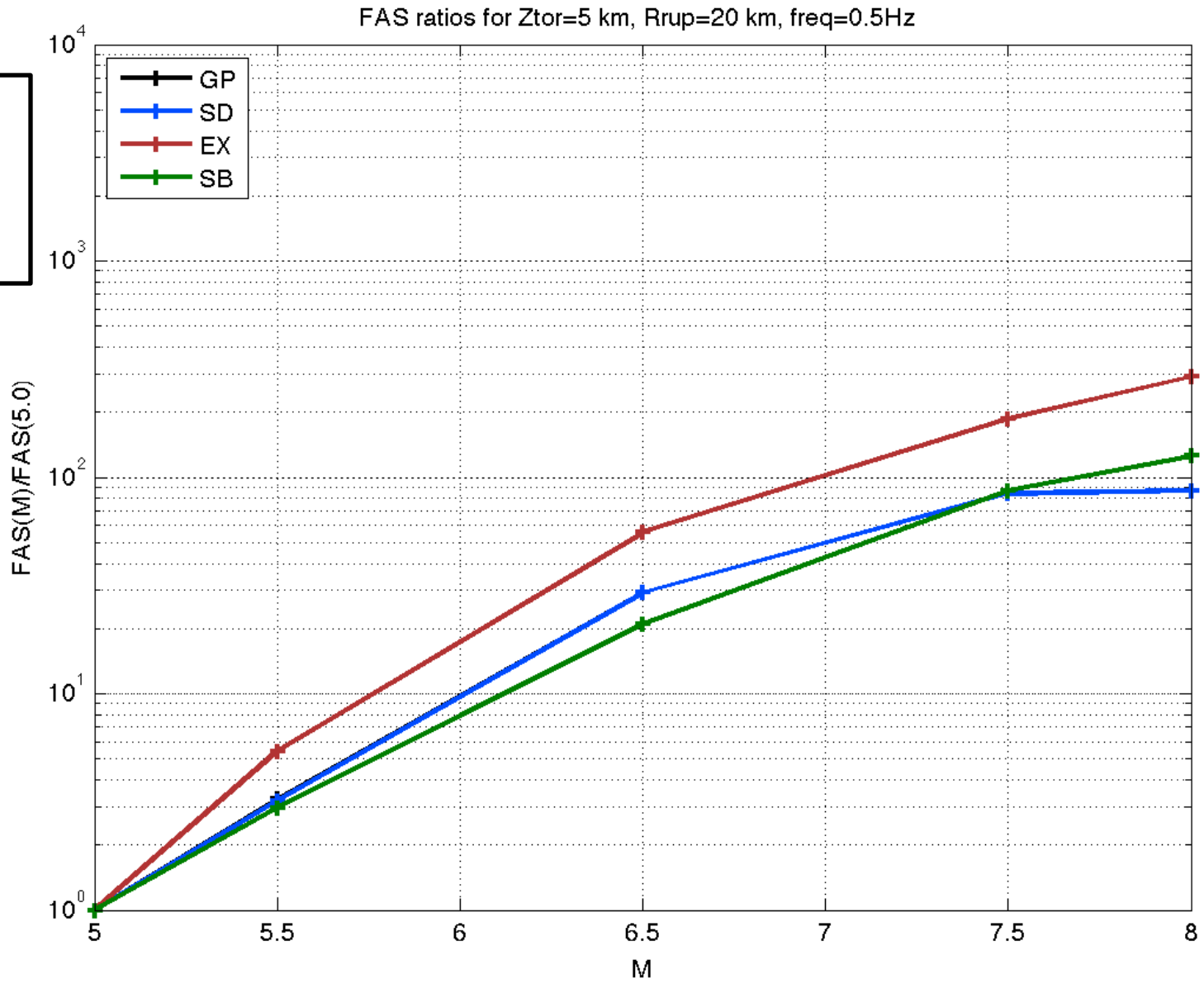
Ztor = 5 km
Rrup = 20 km



FAS Ratio vs. M (4 Methods)

F = 0.5 Hz

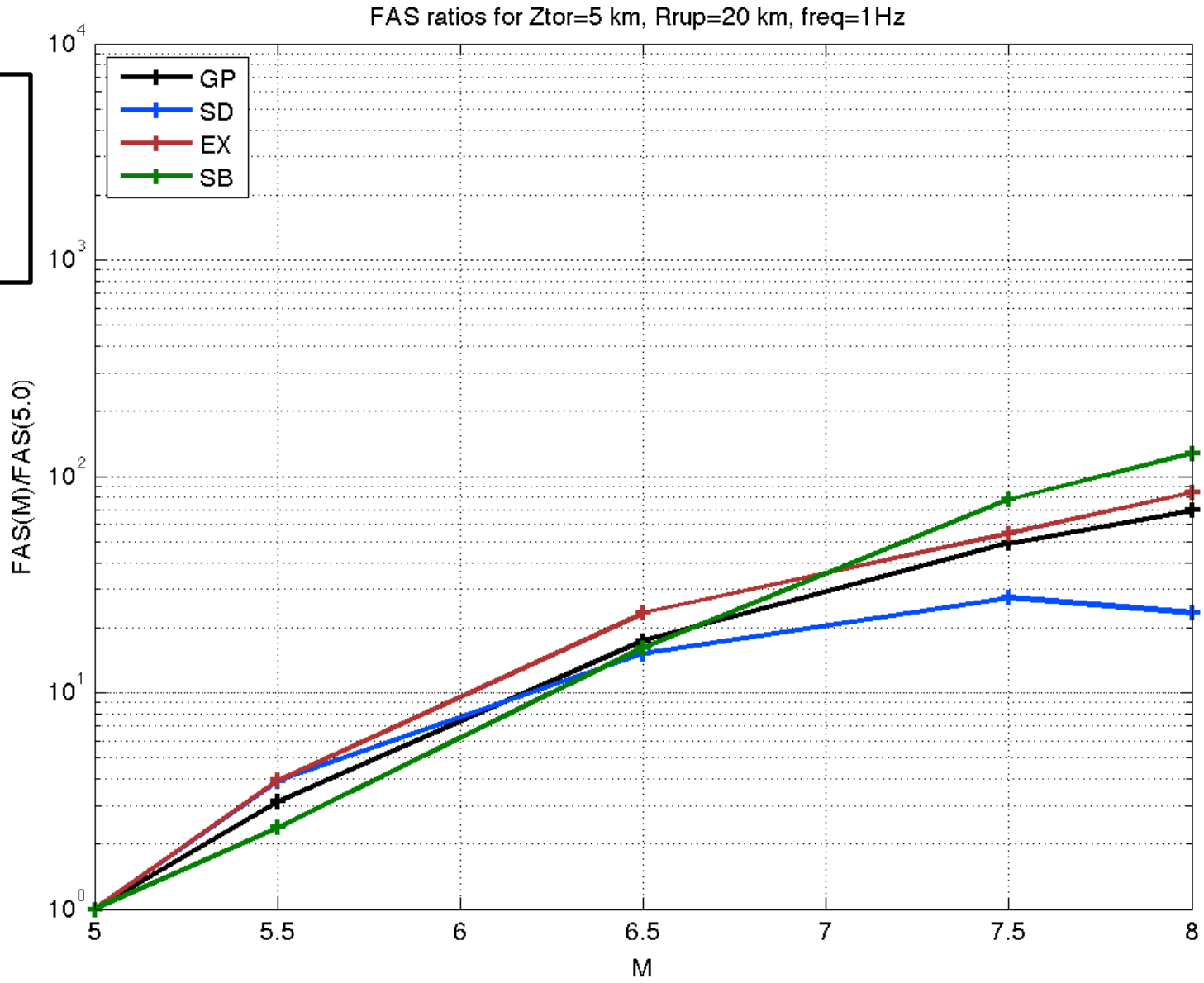
Ztor = 5 km
Rrup = 20 km



FAS Ratio vs. M (4 Methods)

F = 1.0 Hz

Ztor = 5 km
Rrup = 20 km



Products

1. RotD50 spectra for each Rrup ring, plotted with GMPES

2. FAS and RotD50 of individual stations; also averaged and smoothed

3. FAS Ratios relative to M 5.0 case
   - FAS Ratio vs. Frequency
   - FAS Ratio vs. M

4. **Fit of the ratios:**

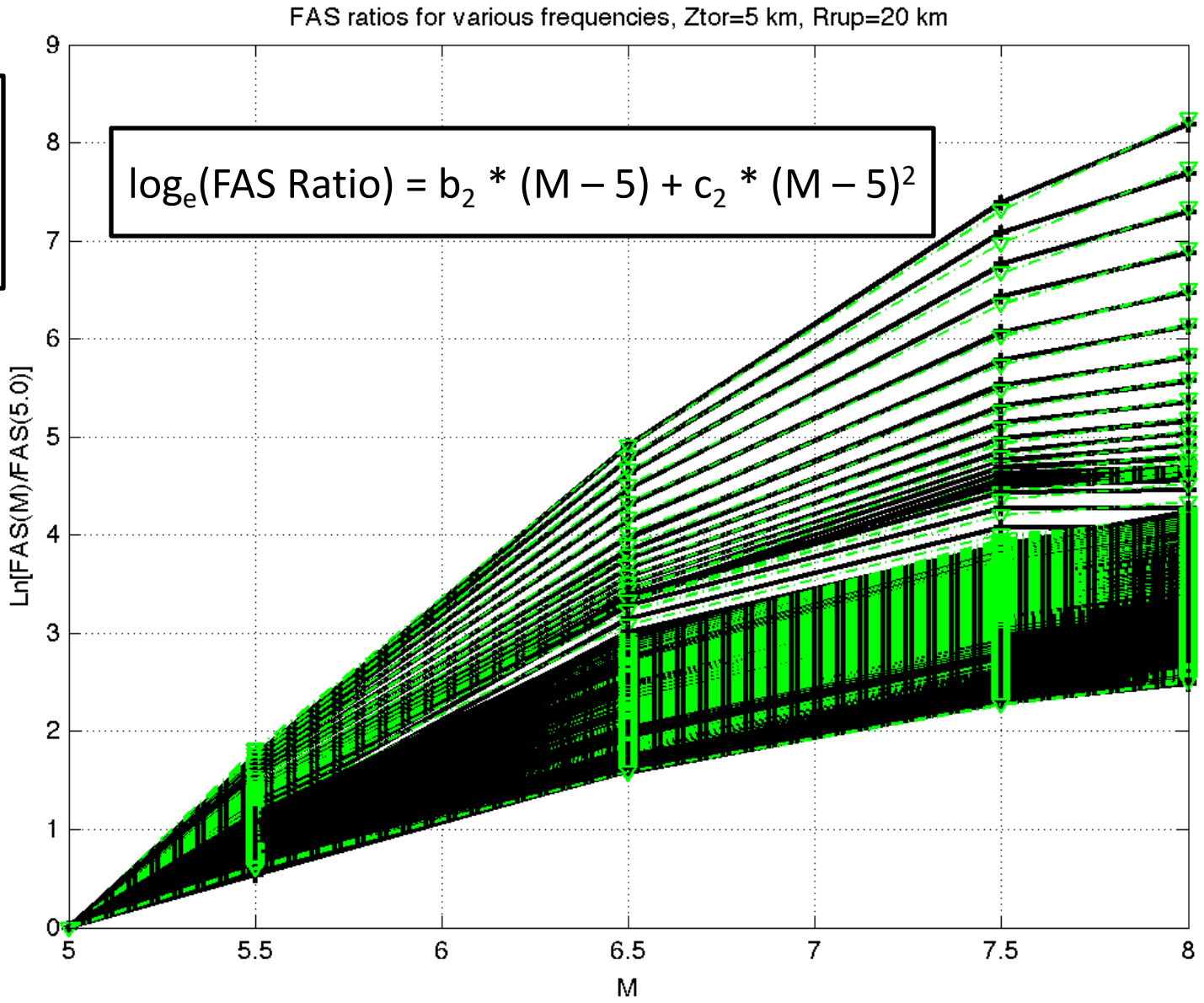
$$\log_e(\text{FAS Ratio}) = b_2 * (M - 5) + c_2 * (M - 5)^2$$

To obtain frequency and distant dependent coefficients b_2 and c_2

FAS Ratio vs. M (4 Methods)

F = 0.05 - 20 Hz

Ztor = 5 km
Rrup = 20 km

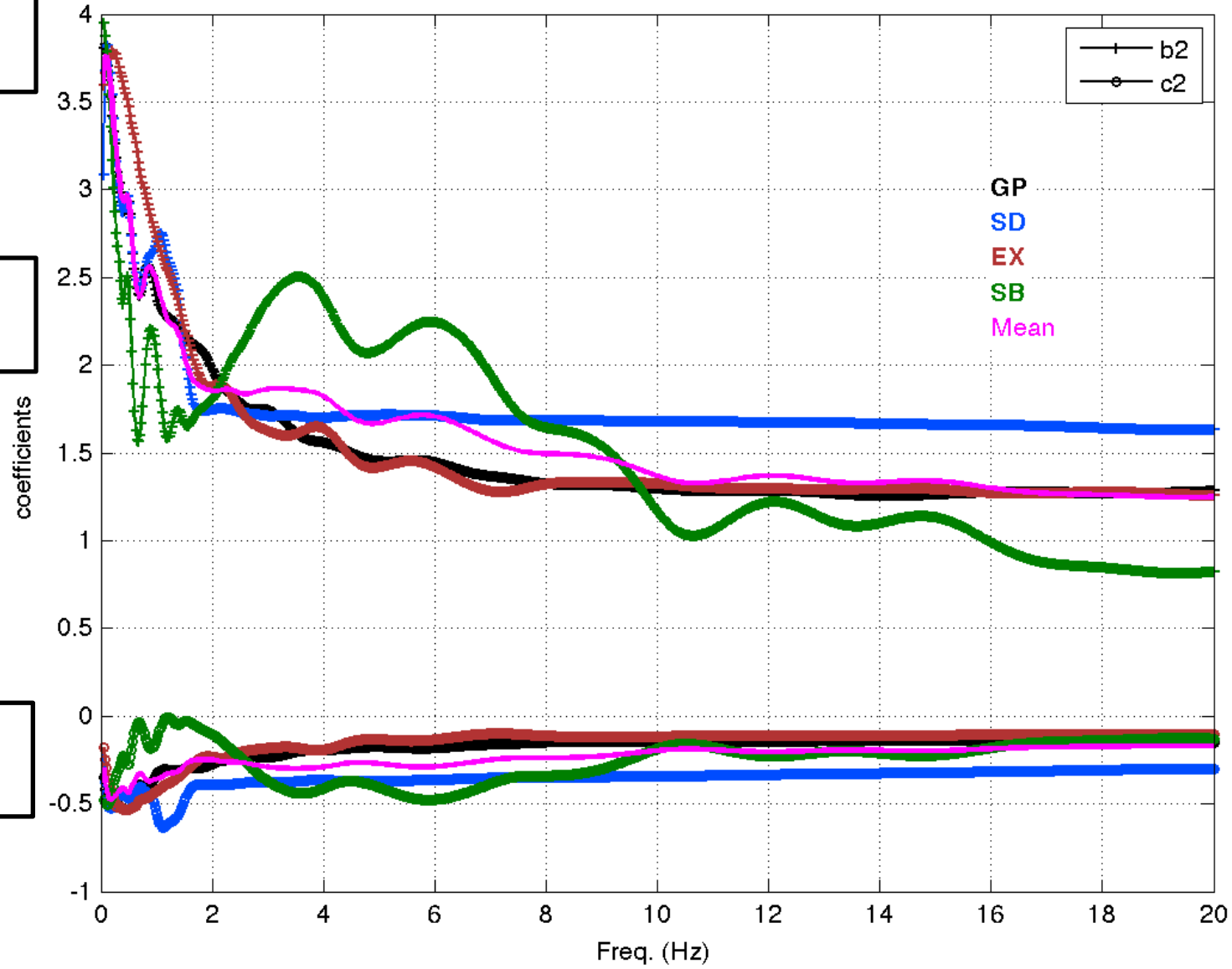


Coefficients: $\log_e(\text{FAS Ratio}) = b_2 * (M - 5) + c_2 * (M - 5)^2$

Ztor = 5 km
Rrup = 20 km

b_2

c_2



Result

Coefficients: $\log_e(\text{FAS Ratio}) = b_2 * (M - 5) + c_2 * (M - 5)^2$

- The coefficients b_2 and c_2, which are frequency and distance dependent, have been incorporated into the empirical FAS model
- The coefficients have been selected from the GP model, and from the Ztor=5 km cases

Future work:

- Smooth model over distances and Ztors
- A similar approach will be used for PSA ratios

- Additional thanks to
  - Fabio Silva, Kim Olsen, Karen Assatourians, Rob Graves, Jorge Crempien, Ralph Archuleta, Norm Abrahamson and Phil Maechling