Point-Source Stochastic Model

Pacific Engineering and Analysis
Bob Darragh
Walt Silva

October 12, 2011

Point-Source Stochastic Model

- Validation in WNA
  - How well does the model fit the observations?
    - Point-source, simple two-parameter model

      M and $\Delta\sigma$
- Single- Verses Double-Corner Models
  - How well do these models fit the observations?

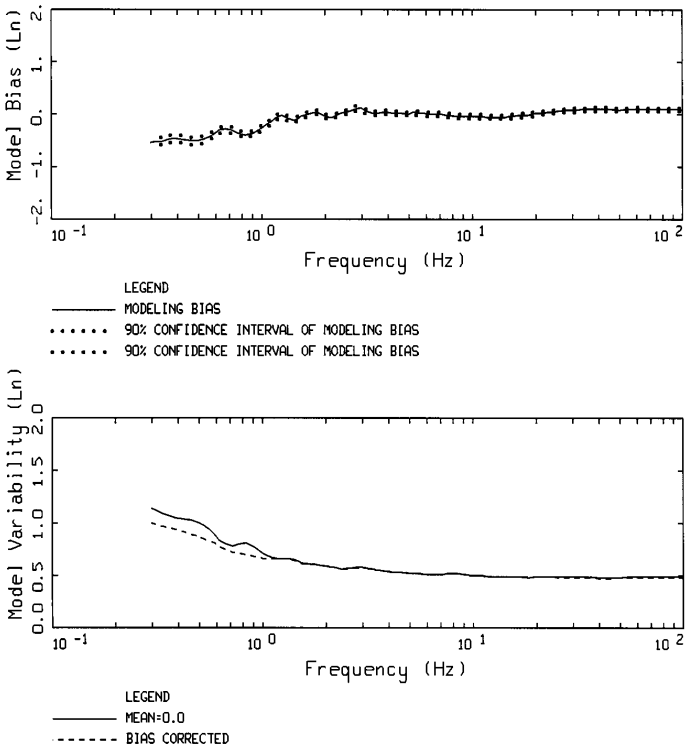
Large Magnitude (Finite Fault) WNA Observations

- Stress Parameter ($\Delta\sigma$)
  - Magnitude
  - Slip Depth (M_o release, Top-of-Rupture)
    - Mechanism
- Data and GMPEs Saturation as f(M)
  - $\Delta\sigma$ (**M**): Magnitude Dependent Stress Parameter
  - $\Delta\sigma$ (fixed), H (**M**): Magnitude Dependent Fictitious Depth :

    For $\mathbf{M} \geq 6.5$: $H = H' e^{a+b\mathbf{M}}$
  - M dependent far-field fall-off
  - G (R (**M**)) = $R^{-(a + b (\mathbf{M} - 6.5))}$

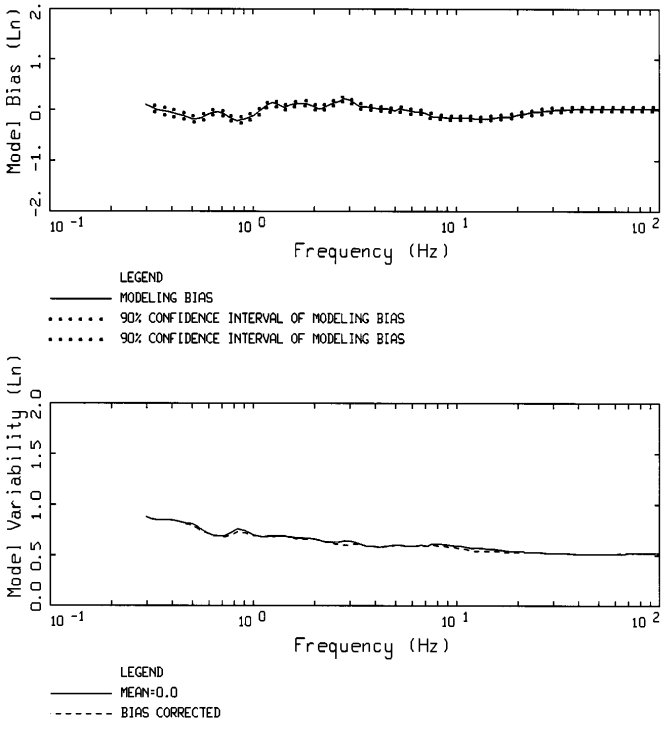
WNA Validation

- Point-Source (single-corner)
- Finite-Source (for comparison)



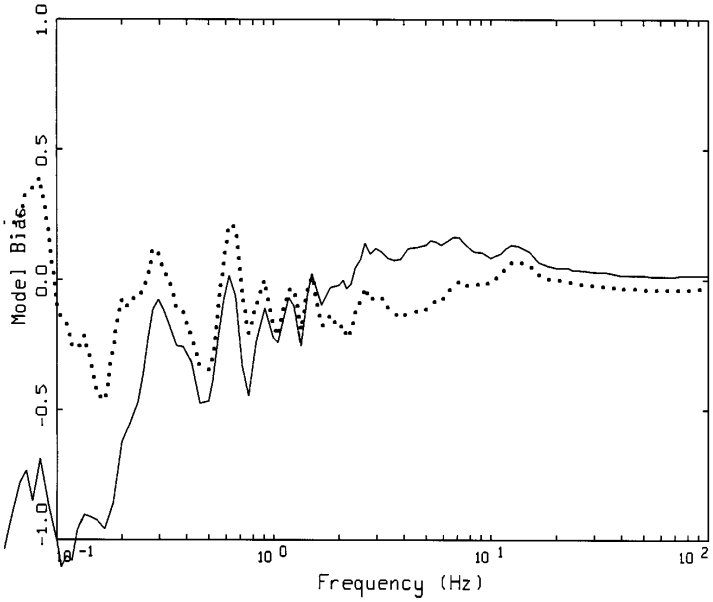
16 EARTHQUAKES POINT-SOURCE
NONLINEAR, ALL 503 SITES

5



15 EARTHQUAKES FINITE-SOURCE
NONLINEAR, ALL 487 SITES

6



DENALI, M = 7.9, MODELING BIAS
22 SOIL SITES

LEGEND
POINT SOURCE MODELING BIAS
FINITE SOURCE MODELING BIAS

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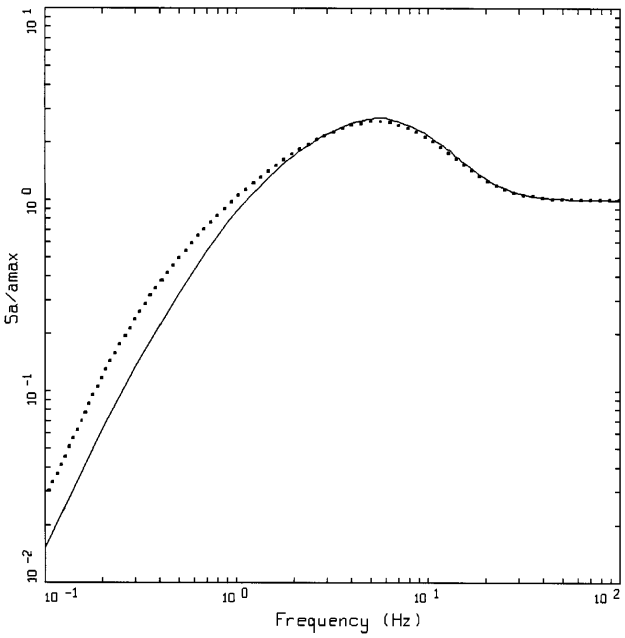

MODEL, M = 6.5, D= 25 KM, 1,2-CORNER
GEOMATRIX AB(550M/SEC), K = 0.05 SEC

LEGEND
2-CORNER
1-CORNER

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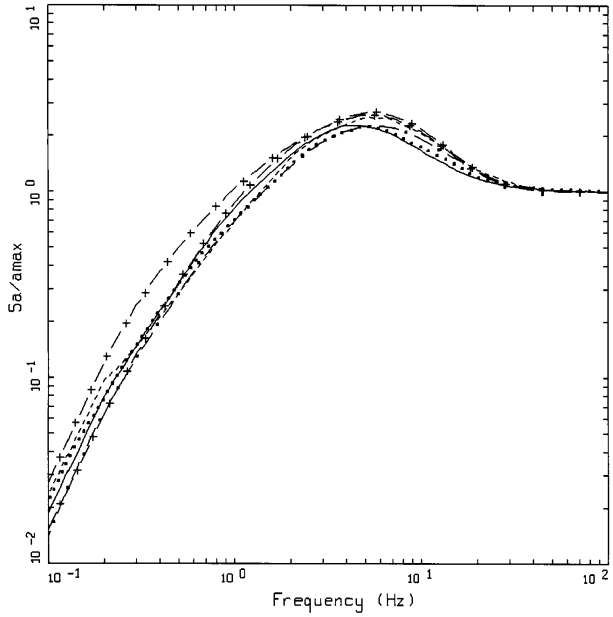

NGA 2008, M = 6.5, D = 25 KM, STRIKE-SLIP
GEOMATRIX AB(550M/SEC)

LEGEND
ABRAHAMSON & SILVA
BOORE & ATKINSON
CAMPBELL & BOZORGNIA
CHIOU & YOUNGS
2-CORNER, K = 0.05 SEC
1-CORNER, K = 0.05 SEC

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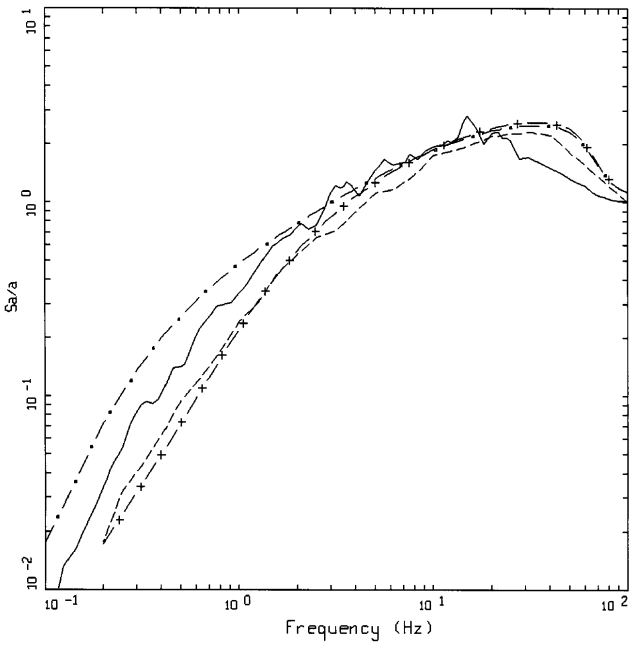

AVERAGE HORIZONTAL SPECTRAL SHAPE, CENA
NAHANNI, M=6.8, ROCK SITES

LEGEND
50TH PERCENTILE
CEUS SINGLE CORNER MODEL(SP = 120 BARS)
CEUS DOUBLE CORNER MODEL(Atkinson, 1993)
ATKINSON AND BOORE(2004)

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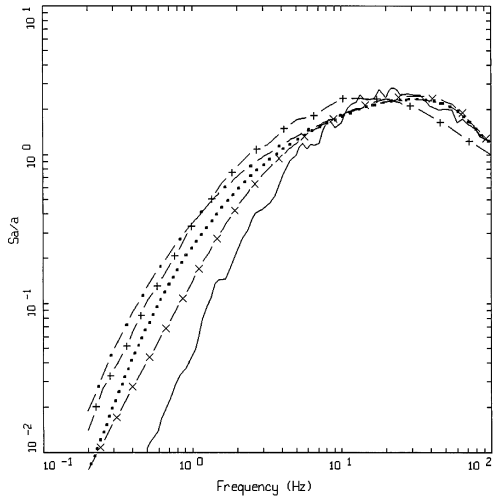

AVERAGE HORIZONTAL SPECTRAL SHAPE, SAGUENAY. M=5.9
STATIONS 16 AND 17

LEGEND
50TH PERCENTILE
CEUS SINGLE CORNER MODEL (SP = 120 BARS)
CEUS SINGLE CORNER MODEL (SP = 500 BARS)
CEUS DOUBLE CORNER MODEL (ATKINSON, 1993)
ATKINSON AND BOORE (2006)

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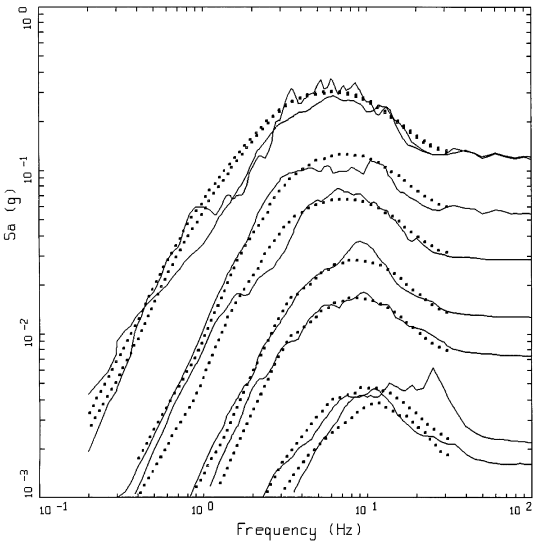

COALINGA RESPONSE SPECTRA
Local Magnitude 2.5 - 5.9

LEGEND
5 %, ALL STATIONS, ML=2.5: AVERAGE OF 12 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=3.0: AVERAGE OF 13 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=3.5: AVERAGE OF 14 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=3.9: AVERAGE OF 10 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=4.2: AVERAGE OF 02 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=4.6: AVERAGE OF 04 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=5.2: AVERAGE OF 16 HORIZONTAL COMPONENTS
5 %, ALL STATIONS, ML=5.9: AVERAGE OF 02 HORIZONTAL COMPONENTS
5 %,
5 %,
5 %,
5 %,

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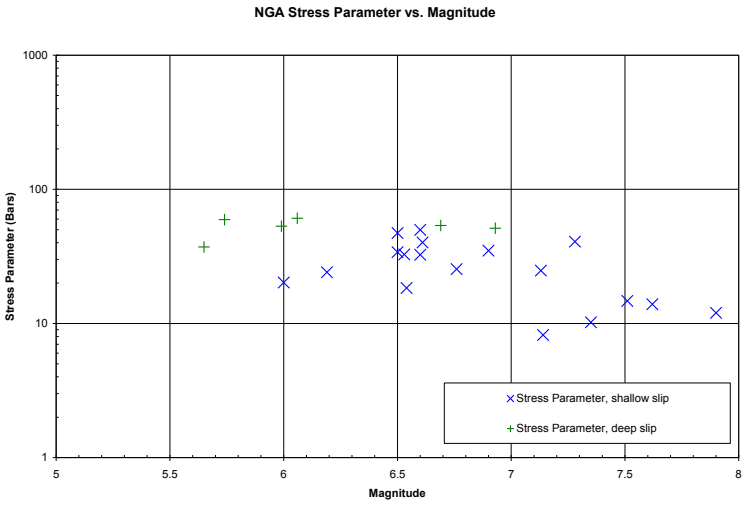
WNA STRESS PARAMETER OBSERVATIONS

- Decreases as magnitude (**M**) increases
- Varies with fault mechanism (Nm<SS<Rv)
- Increases as slip depth or depth to Top-of Rupture (TOR) increases.



Estimates of stress parameter computed for the 24 NGA earthquakes verses magnitude (**M**). Shallow slip defined as greater than (or equal) 20% moment released to a depth of 5 km. Deep slip with less than 20% moment released over the top 5 km of the crust.

Preliminary Stress Parameters Based On Inversions Of NGA GMPEs									
Includes Rock ($\overline{v_s}$ (30m) 550m/sec) and Soil Sites ($\overline{v_s}$ (30m) = 270m/sec, Default TOR									
M	Δσ (bars) Strike Slip			Δσ (bars) Normal[1]			Δσ (bars) Reverse[1]		
5.5	66.1			62.8			86.4		
6.5	45.8			39.2			55.4		
7.5	23.8			22.4			28.9		
Median	41.6			38.0			51.7		
Rock Sites Only($\overline{v_s}$ (30m) 550m/sec)									
	Δσ (bars) Strike Slip			Δσ (bars) Normal[1]			Δσ (bars) Reverse[1]		
M	Shallow	Deep	Default	Shallow	Deep	Default	Shallow	Deep	Default
5.5	46.6	59.0	57.6	45.4	58.0	56.1	54.4	69.7	67.9
6.5	43.9	57.8	49.4	41.9	55.8	44.4	49.8	66.4	52.8
7.5	33.9	45.9	35.2	33.2	44.1	33.6	37.5	51.2	39.1
Median	41.1	53.9	46.4	39.8	52.2	43.7	46.7	61.9	52.0
Top of Rupture (km)									
M	Default			Shallow Slip			Deep Slip		
5.5	6.0			0.0			6.8		
6.5	2.0			0.0			6.8		
7.5	0.7			0.0			6.8		

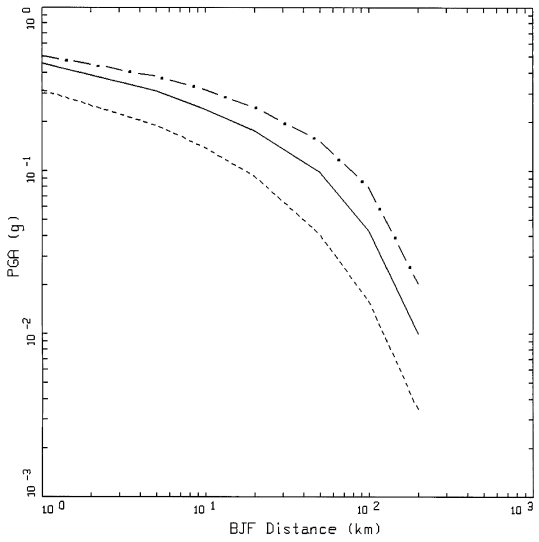
[1]45° dip, sites not hanging wall, not foot wall

Large Magnitude Observations

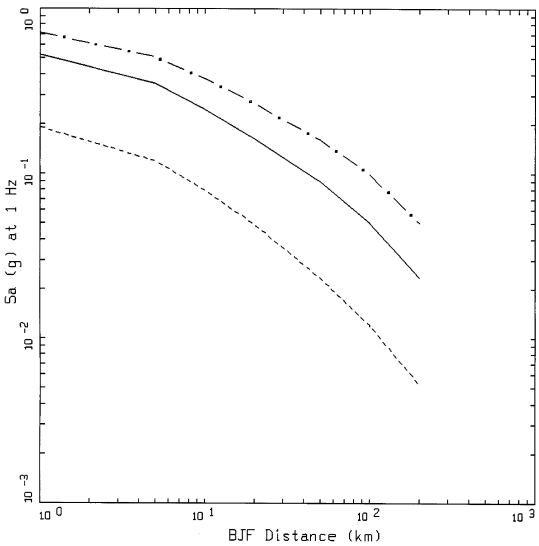
- Saturation
  - Δσ (**M**): Magnitude Dependent Stress Parameter
  - Δσ (fixed), H (**M**): Magnitude Dependent depth

    For $M \geq 6.5$: $H = H' e^{a+b\mathbf{M}}$

  - G (R (**M**)): **M** dependent far-field fall-off
  - G (R (**M**)) = $R^{-(a + b (\mathbf{M} - 6.5))}$



PEER-NGA BOORE AND ATKINSON
VS30= 270 M/SEC, STRIKE-SLIP



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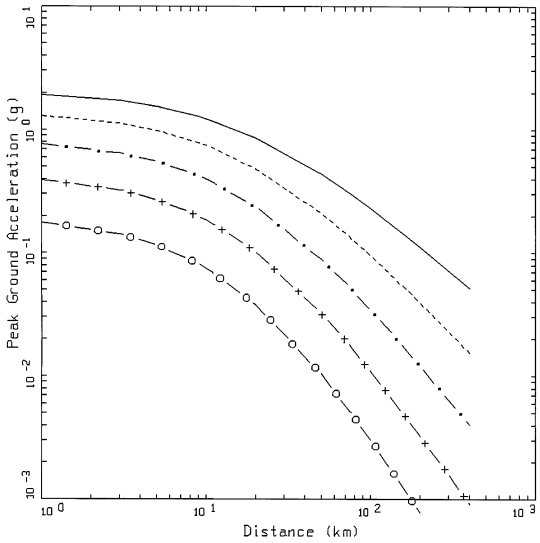
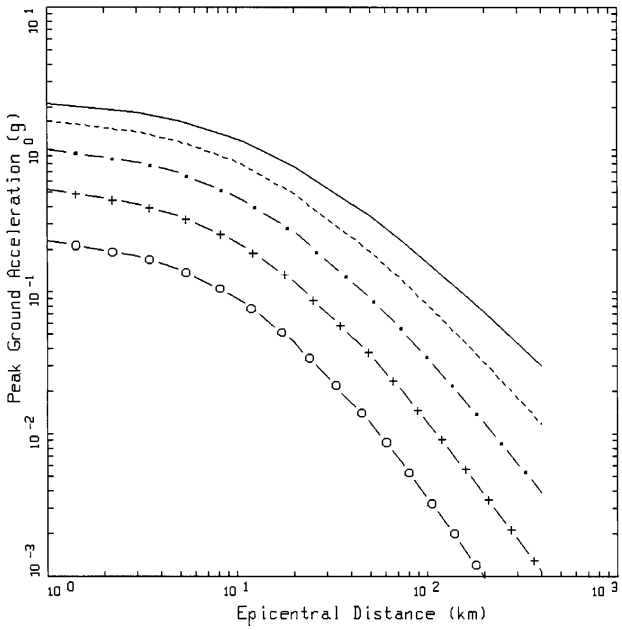


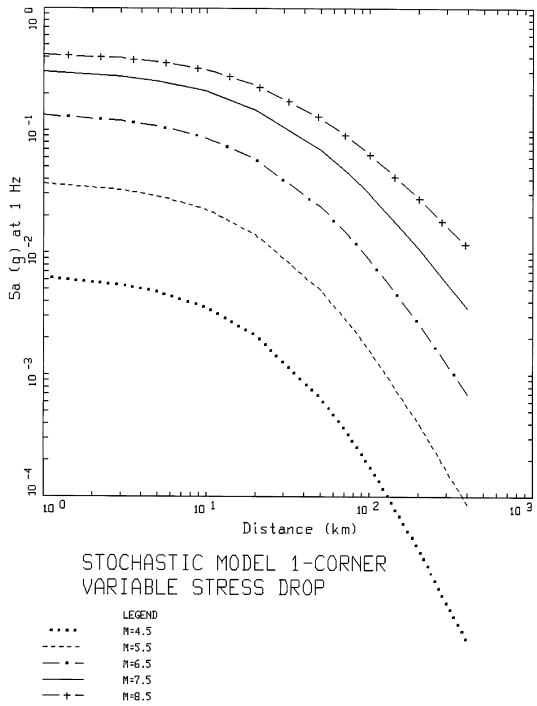
1 CORNER CONSTANT STRESS DROP
MIDCONTINENT, PGA

LEGEND
M=8.5 WITH SATURATION, STRESS PARAMETER = 120 BARS
M=7.5 WITH SATURATION, STRESS PARAMETER = 120 BARS
M=6.5 WITH SATURATION, STRESS PARAMETER = 120 BARS
M=5.5 WITH SATURAITON, STRESS PARAMETER = 120 BARS
M=4.5 WITH SATURATION, STRESS PARAMETER = 120 BARS



1 CORNER VARIABLE STRESS DROP
MIDCONTINENT, PGA

LEGEND
M=8.5, SD = 70 BARS
M=7.5, SD = 90 BARS
M=6.5, SD = 120 BARS
M=5.5, SD = 160 BARS
M=4.5, SD = 160 BARS



Point-Source Stochastic Model

- Validation in WNA
  - Acceptable point- and finite-source models
- Double-Corner Model: Updates
  - accommodate event specific properties
    - high-frequency scaling (variable $\Delta\sigma$)
    - intermediate-frequency sag (e.g. f_a, f_b, ε)

Point-Source Stochastic Model

- Saturation and Stress Parameter
  - WNA GMPEs and data saturate with increasing M
    - Stress parameter decreases with M
    - Magnitude Dependent Fictitious Depth

- **M** dependent far-field fall-off

  $G(R(\mathbf{M})) = R^{-(a + b(\mathbf{M} - 6.5))}$

  a = 1.0296

  b = -0.0422

MODEL LIMITATIONS – SINGLE CORNER

- Saturation

- Geometric Spreading

- Over-prediction of low frequency motion at **M**>6.5

Point-Source Stochastic Model

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Appropriateness of Point Source Distance Metric

NGA-West GMPEs

- **M** 5.5, 6.5, 7.5
- R 1, 5, 10, 20, 50, 100, 200 km
- Soft Rock (Vs30 = 550 m/sec)

Summary

Point Source Issues For CENA

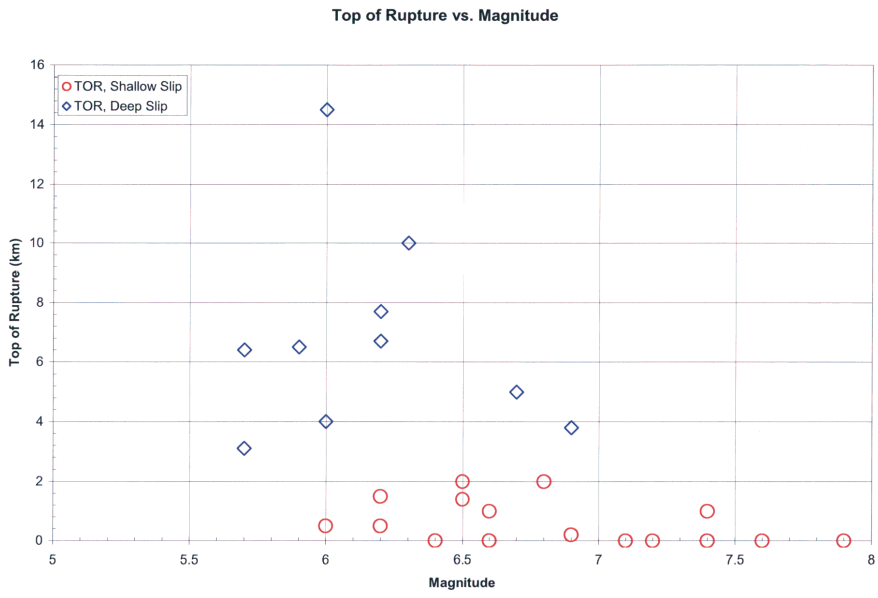
– Range in Δσ at large **M**
  - Intensity Data (**M**)
  - Relic Liquefaction (Δσ)

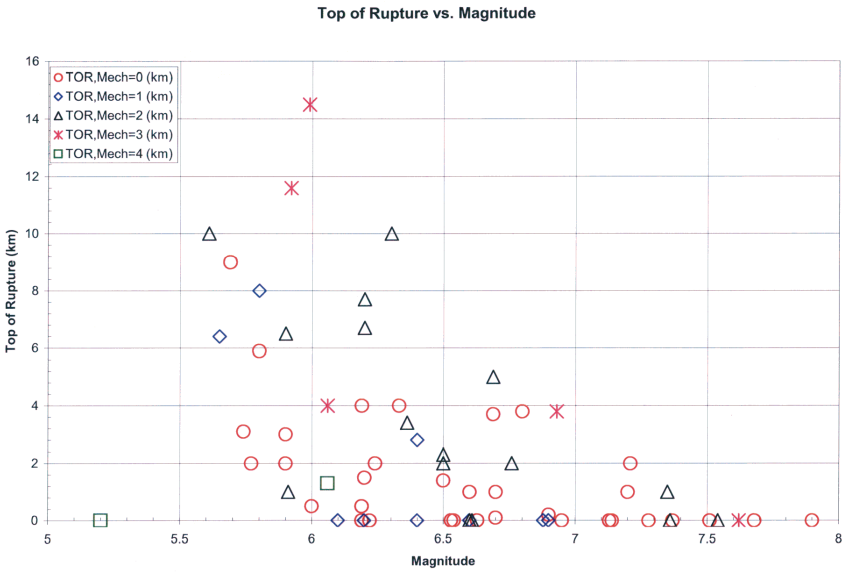
– Saturation
  - Δσ (**M**, H)
  - $H = H' e^{a+b\mathbf{M}}$

– Δσ (**M**,TOR, Mechanism)
  - Coupling of Δσ and H (fictitious depth)

– Spectral Sag
  - Compare Active vs Stable Continental Regions using large **M** sources (regional or teleseismic) (e.g. work by Jack Boatwright (USGS))
  - define range (frequency and amplitude) of sag

– 2-corner point source model
  - Update\revise to accommodate event specific properties
    - high-frequency scaling (variable Δσ)
    - intermediate-frequency sag (e.g. f_a, f_b, ε)





WNA Validation Studies

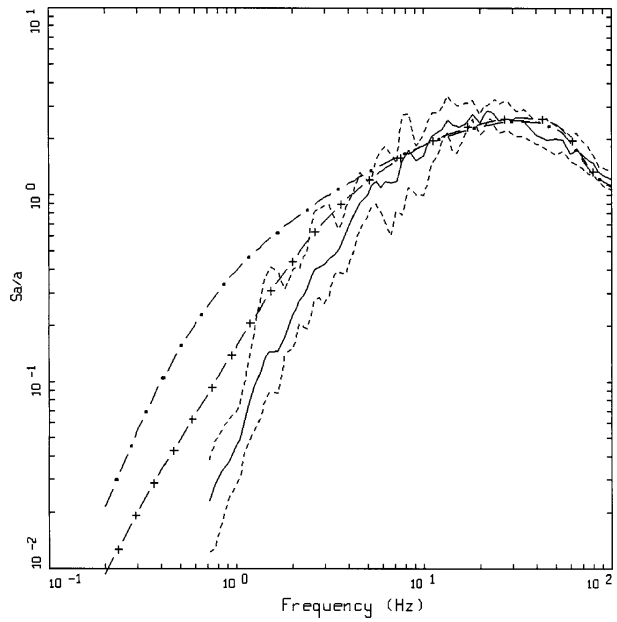
NGA-West GMPEs

- **M** 5.5, 6.5, 7.5
- R 1, 5, 10, 20, 50, 100, 200 km
- Soft Rock (Vs30 = 550 m/sec)

Point-Source Models

- Validations

- Single Verses Double Corner
  - Spectral Shapes
    - WNA
    - CENA



AVERAGE HORIZONTAL SPECTRA, SAGUENAY, M=5.9
STATION 16, 17

LEGEND
50TH PERCENTILE
MINIMUM ENVELOPE
MAXIMUM ENVELOPE
CEUS SINGLE CORNER MODEL(SP = 120 BARS)
CEUS DOUBLE CORNER MODEL(Atkinson, 1993)

Point-Source Stochastic Model

- Saturation
  - $\Delta\sigma$ (**M**)
  - $\Delta\sigma$ (fixed), H (**M**)
- G (R (**M**))
  - $R^{-(a + b (\mathbf{M} - 6.5))}$
- Distance Metric
  - Consistency, Validation and Forward Predictions

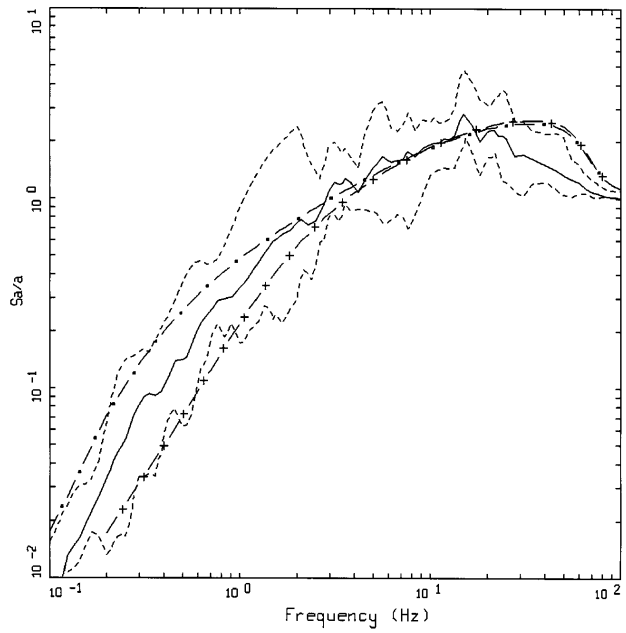
Point Source Issues For CENA

- $\Delta\sigma$ (**M**,TOR, Mechanism)
- Spectral Sag
  - Compare Active vs Stable Continental Regions using large **M** sources (regional or teleseismic) (e.g. work by Jack Boatwright (USGS))
  - define range (frequency and amplitude) of sag

Appropriateness of Point Source Distance Metric

- JB Distance
  - **M** Dependent Depth
  - Depth to Largest Asperity

NGA-WNA Crustal Earthquakes with Stress Parameter (preliminary estimates by Dr. Yun at KEPRI)			
Slip Depth	Number of earthquakes	Stress Parameter (bars)	σ_{ln}
All	24	28.8	0.59
Shallow	18	23.9	0.54
Deep	6	52.0	0.18



AVERAGE HORIZONTAL SPECTRAL SHAPE, CENA
NAHANNI, M=6.8, ROCK SITES

LEGEND
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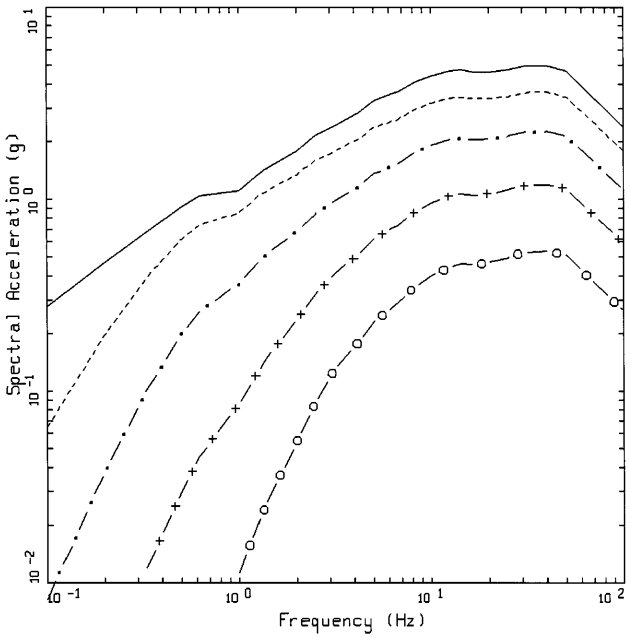

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MIDCONTINENT, PSA, D = 1 KM

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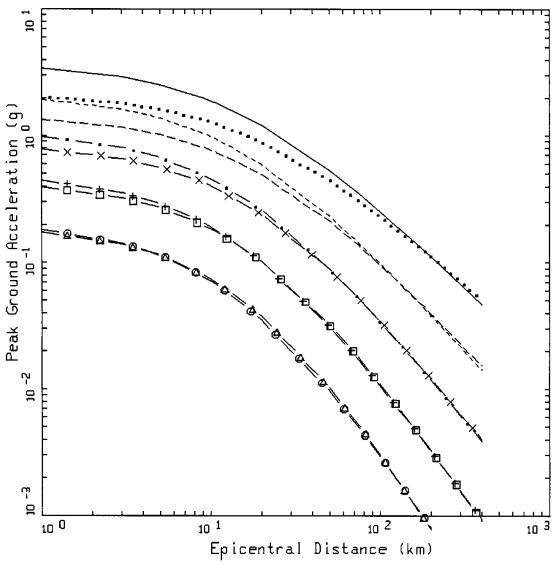
40



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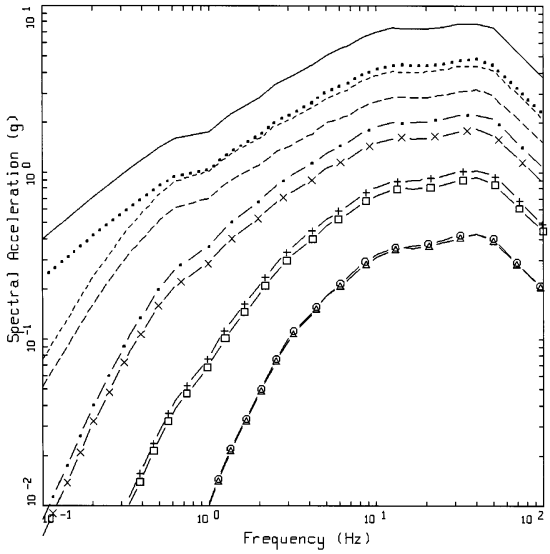
M=4.5 WITH SATURATION, SD = 120 BARS

41



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