Ground Motion Database for SCRs: Development, Attributes, and Products

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Special Session at SMiRT-22

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Goal: ground motions and metadata for development of new ENA ground-motion prediction equations

- ENA data: complete for magnitude >= 4 + well-recorded smaller earthquakes (mag >= ~2.5)
- Data from other SCRs (e.g. Australia, India, Europe, Argentina – data under review)
- Uniform processing & QA
- Metadata (e.g., location, magnitude, Vs30, etc.)
- Products similar to NGA West

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ENA Data Sources

- Very old records (poor quality, long-period only)
  - 1925 M6.4 Charlevoix
  - 1929 M7.2 Grand Banks
  - 1935 M6.2 Timiskaming
  - 1944 M5.8 Cornwall-Massena

- Older strong-motion & short-period (variable quality)
- Modern broadband (ANSS, TA, regional networks)
  - Thousands of new records (since ~1990)
  - Sources IRIS DMC, CNDC, and regional networks

- Modern strong-motion (Etna,IA,Netquake,ANSS)

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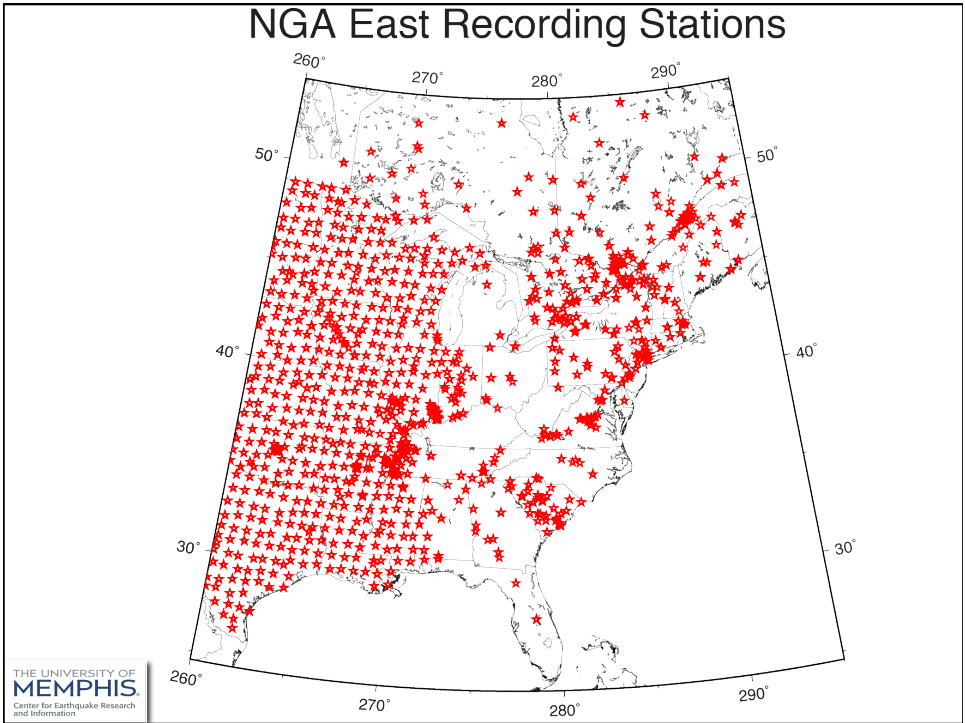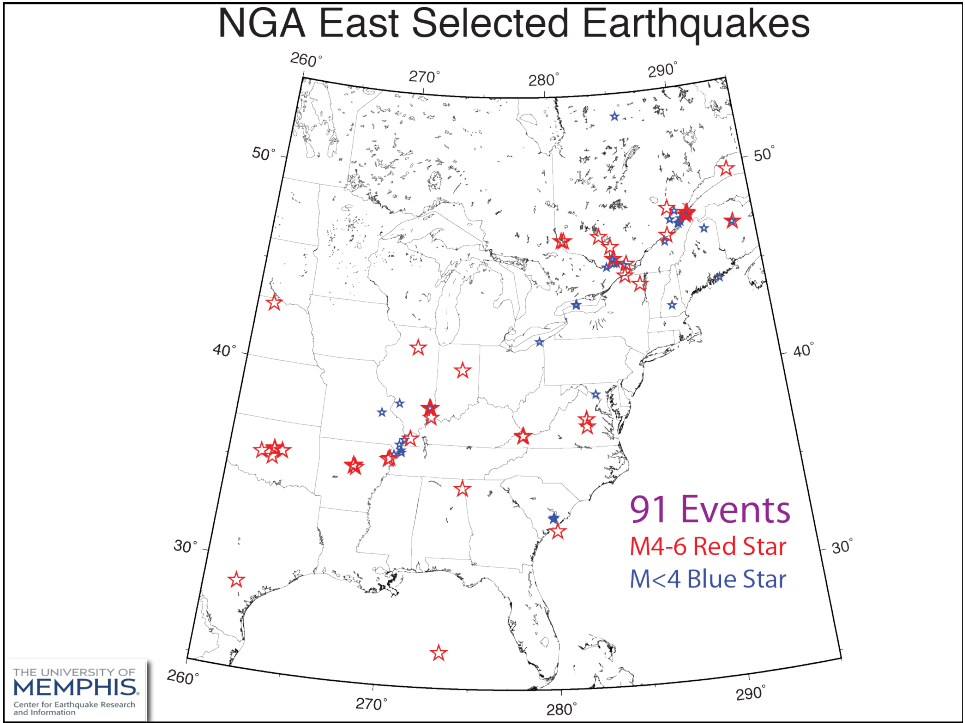Center for Earthquake Research and Information
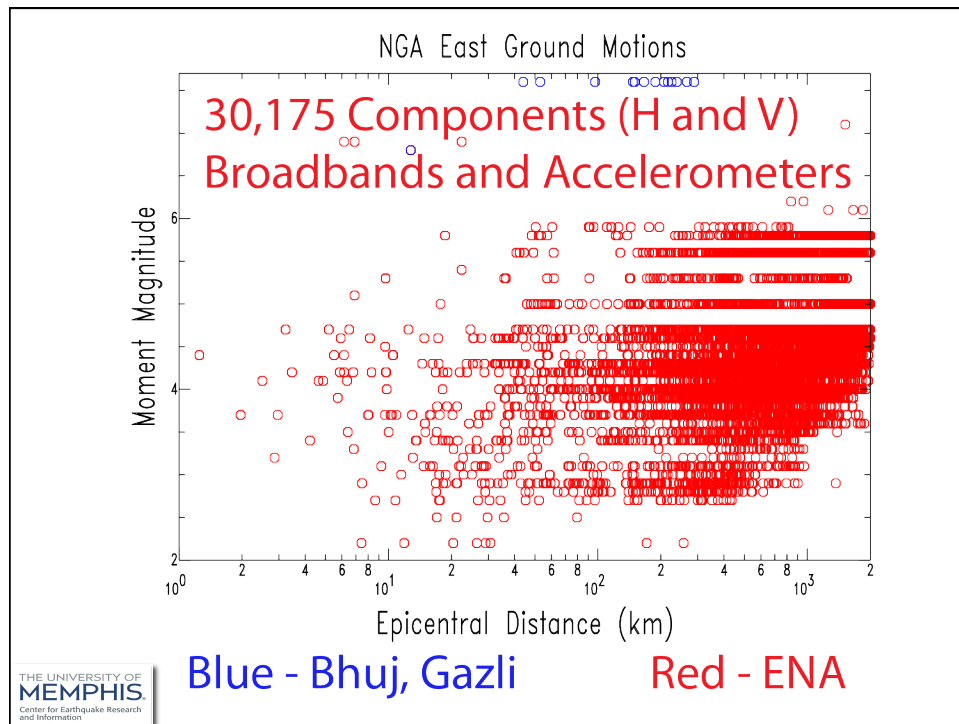

ENA data in final review!

- ✓ 91 earthquakes, through 2011 Mineral VA, Sparks OK
- ✓ GM flatfiles: PGA + PGV + PGD + 105 periods (0.01-10s) ASIS 5% damped and GMRotD50 & GMRotD100 for 5 damping levels
- ✓ Waveforms

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Overview

- Summary

- Selection Criteria

- Data Processing and Time Series Files

- Data Quality Assurance

- Model Bias Comparisons with Current GMPEs

- Q Boundary Locations and Initial Empirical GMPE

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Summary

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NGA East Selected Earthquakes

91 Events
M4-6 Red Star
M<4 Blue Star

NGA East Recording Stations

Data Selection

- Initial Focus was on available M$\geq$4 ENA Earthquakes since January 1, 2000 plus important older events since 1980.
- Added additional M 2.5 to 4.0 events with 5 or more stations within 100 km.
- Selected and Collected Data for 51 M$\geq$4 Events and 38 M<4 Events, plus 2001 M7.6 Bhuj, India and 1976 M6.8 Gazli earthquake data.
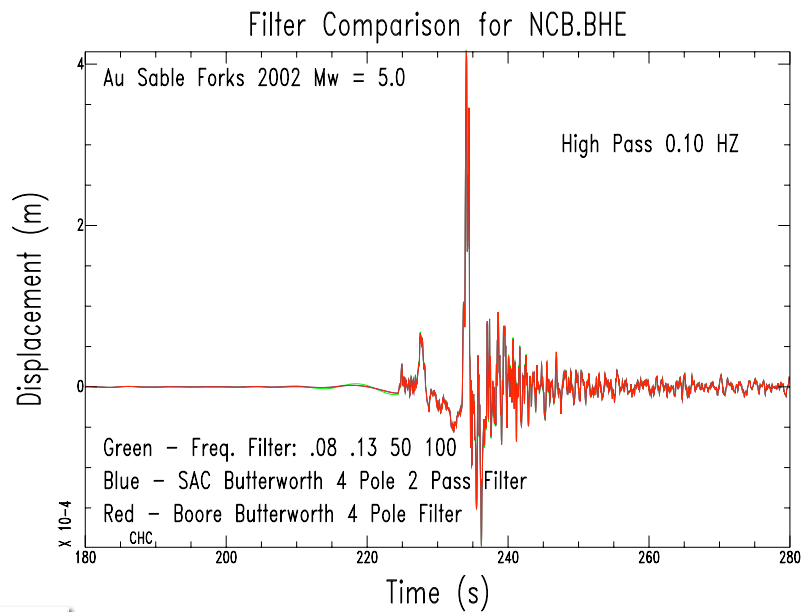
Data Processing

Summary of Processing

- Data Processing using Seismic Analysis Code (SAC)
- Download Uncorrected Waveforms and PZ Files
- Review Waveforms for Obvious Problems
- Instrument Correction and Initial Filtering
- Generate Signal and Pre-event Noise Spectra and Select Final Filter Corners
- Final Bandpass Filtering for Acc, Vel, Dsp
- Extract NGA Ground Motion Values (PGA, PGV, PGD, and 105 Sa)

Instrument Correction and Filtering

- Instrument Correction
  - Remove Mean, Detrend (linear), 2% Cosine Taper
  - SAC TRANSFER Function
  - PZ Files (for Displacement)
  - Successively Specify Acc, Vel, none (Dsp)
- Waveform Filtering
  - Frequency Domain, Acausal, Cosine-Tapered Bandpass Filter in SAC TRANSFER Function
  - Checked via Dave Boore's Processing and Butterworth Filtering (same results)

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Filter Comparison for NCB.BHE

Au Sable Forks 2002 Mw = 5.0

High Pass 0.10 HZ

Green — Freq. Filter: .08 .13 50 100
Blue — SAC Butterworth 4 Pole 2 Pass Filter
Red — Boore Butterworth 4 Pole Filter

CHC

Displacement (m) X 10-4

Time (s)

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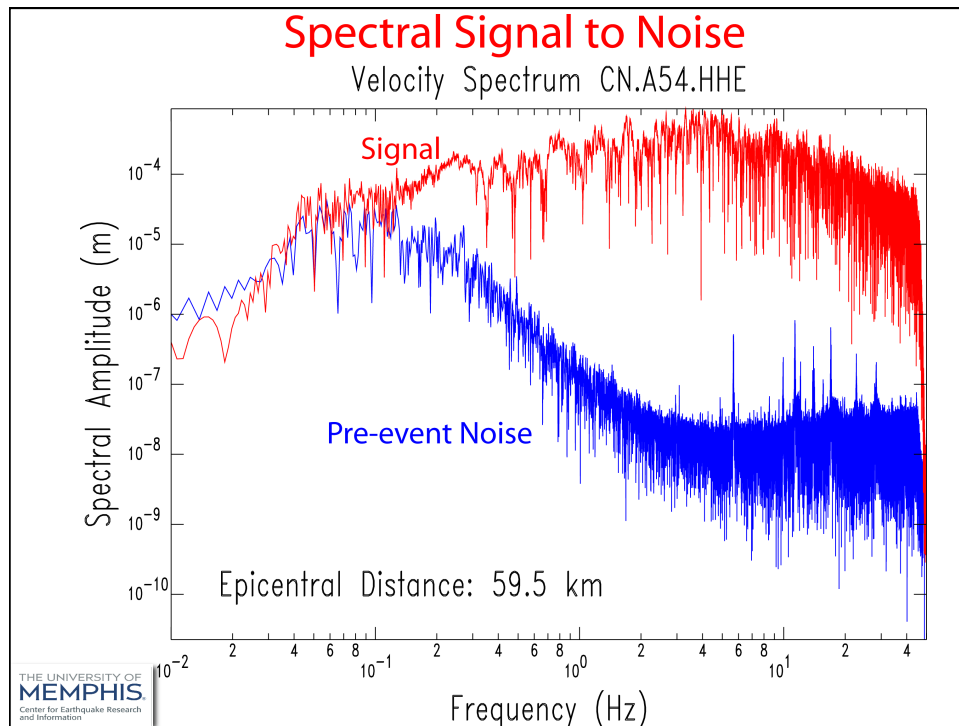# Time Series

NGA East Time Series Files

- Produced from SAC acc, vel, and dsp files

- ASCII files are in NGA format

Data Quality Assurance

Quality Assurance

- Examine Original Waveforms
  - Clipping/Distortion
  - Missing Data / Noise Spikes, etc.
- Determine Spectral Signal to Noise
  - Final Filter Selection
- Review Acc and Disp Record Quality
  - If needed, adjust record length, filtering
- Plot PGA (PGV) vs. Distance
  - PZ or Instrument Problems (outliers)
- Build Waveform Quality Table for each Event

Spectral Signal to Noise

Velocity Spectrum CN.A54.HHE

Signal

Pre-event Noise

Epicentral Distance: 59.5 km

Spectral Amplitude (m)

Frequency (Hz)

New Quality Assurance Efforts

- Check on Horizontal Time Series Alignment for GMrotD
  - Run Cross-Correlation on all pairs
  - Check and Correct or Eliminate Uncorrelated pairs (>30s difference)
- Systematically check Station coordinates among events
  - List each record's Lat, Lon, Elev, Stn ID
  - Sort on Stn ID and compare
  - Correct any discrepancies (> 1 km in Lat, Lon)

New Quality Assurance Efforts (Cont.)

- Selective review of processed data at PEER:
  – Check on Fourier and Response Spectra
  – Check on filtering corner frequencies (high, low)
  – Inspection of waveforms

- Further processing for acceleration time histories so as to be more useful to engineering community (signal portion only and integrates to velocity and displacement w/o baseline slope).
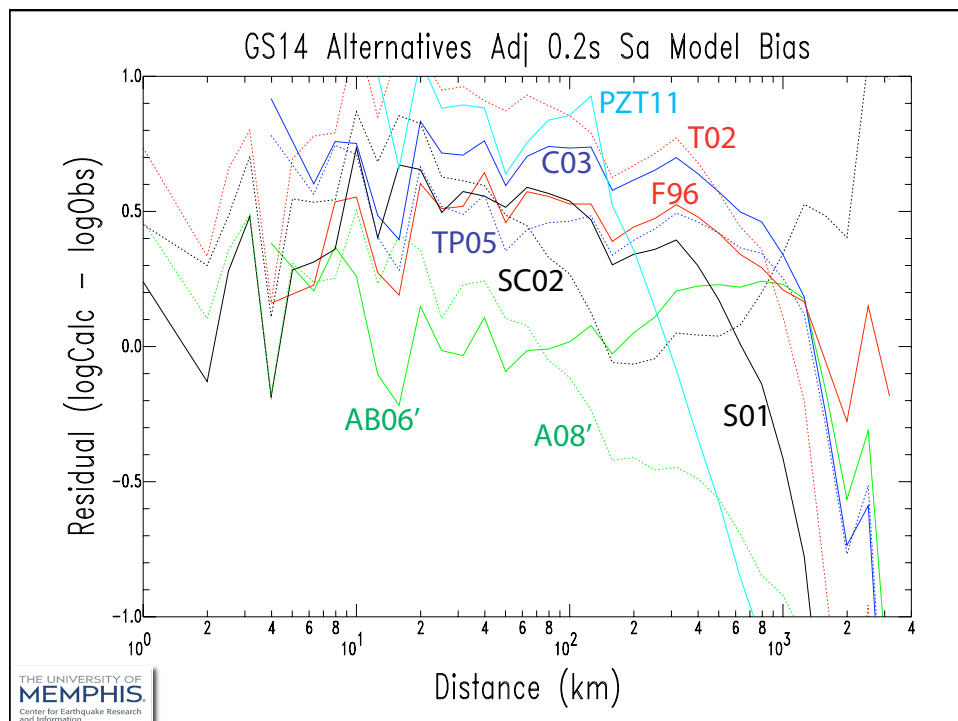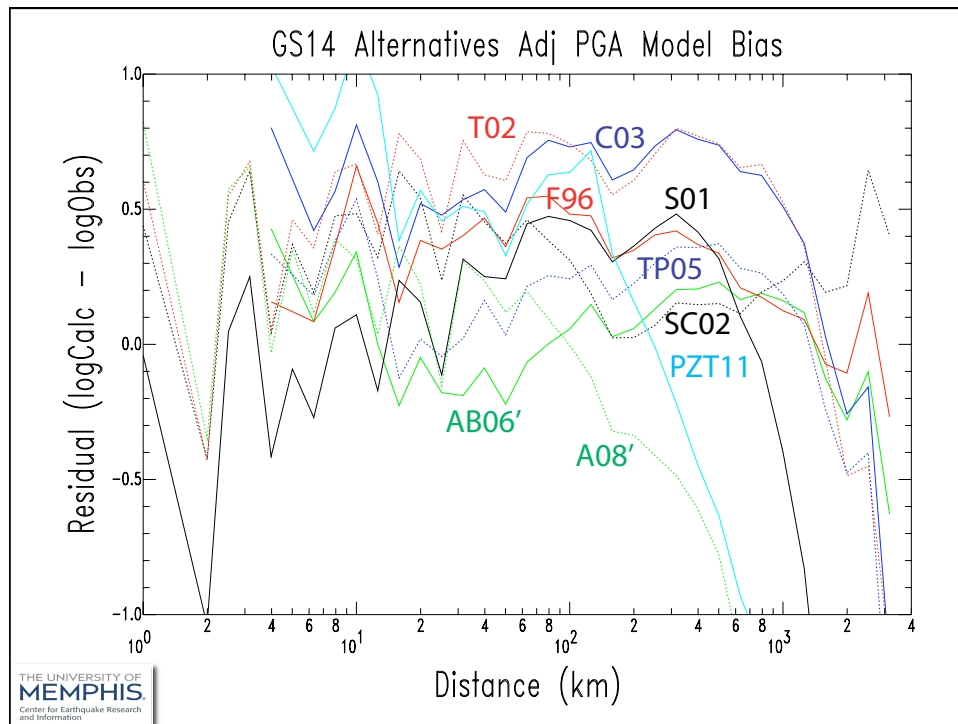
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Model Bias Residual Comparisons for Current ENA GMPEs

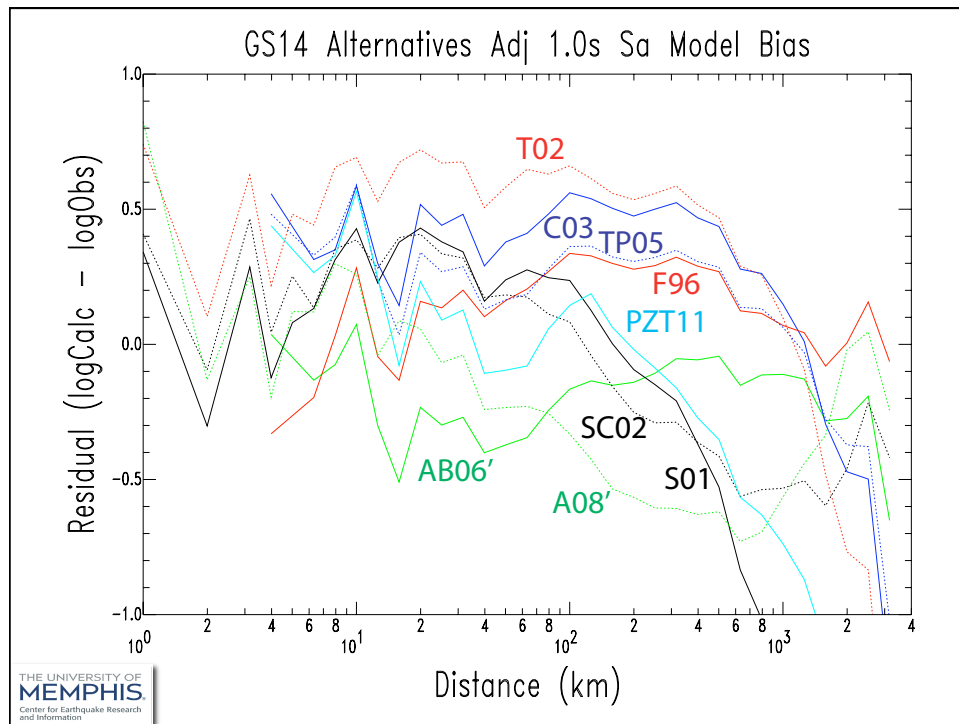THE UNIVERSITY OF
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Residual Analysis Approach

- Form log(Calc) minus log(Obs) model bias residuals

- Can adjust for soil condition at site (HR or B/C)

- Determine mean, standard deviation, and 95% confidence limits for 0.1 log(dist) bins.

- Compare mean residuals for distances < 100 km

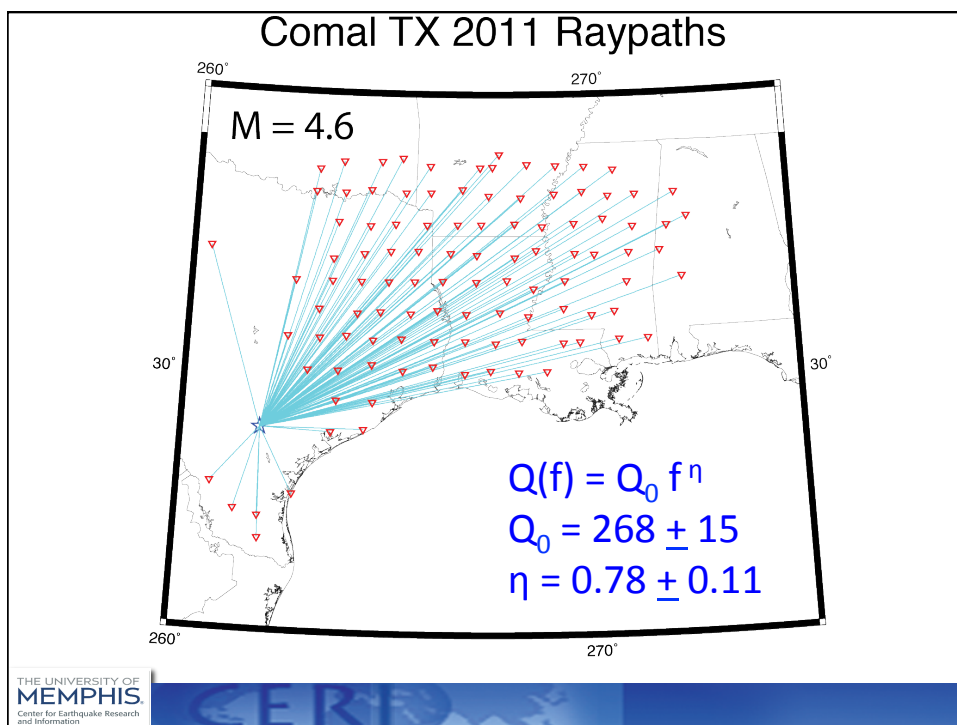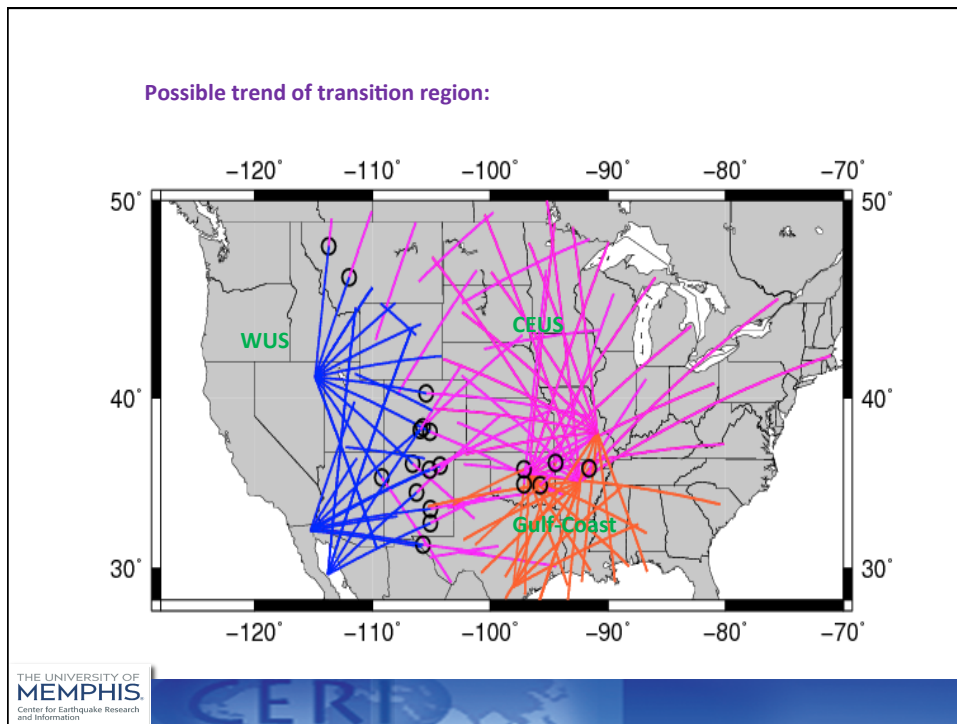THE UNIVERSITY OF
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Results

- GMPEs proposed for 2014 USGS NSHMP maps
  - PGA
  - 0.2 s Sa
  - 1.0 s Sa

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GS14 Alternatives Adj 1.0s Sa Model Bias

Identifying Location of Boundaries Between Q Regions

Possible trend of transition region:

Comal TX 2011 Raypaths

M = 4.6

$$Q(f) = Q_0 \, f^{\eta}$$
$$Q_0 = 268 \pm 15$$
$$\eta = 0.78 \pm 0.11$$

Sullivan 2011 Raypaths

M=3.9

$Q(f) = Q_0 \, f^{\eta}$
$Q_0 = 586 \pm 65$
$\eta = 0.46 \pm 0.11$

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New Empirical ENA GMPE

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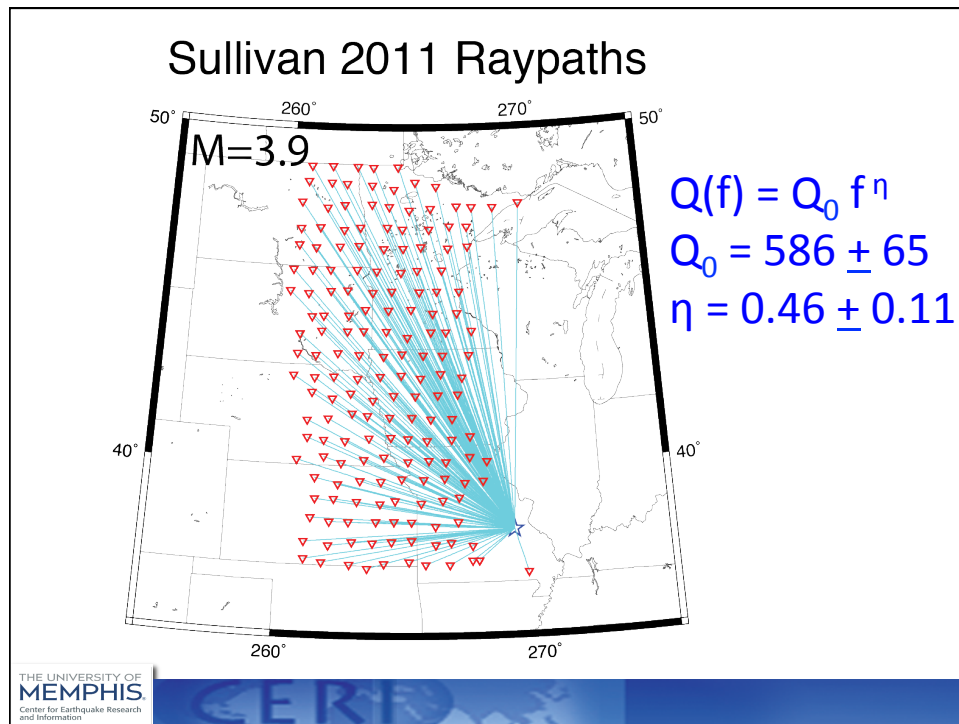
Value

- Test Flatfiles and Functional Form
- Explore NGA East Ground Motion Database
- Find its Limitations

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Initial Functional Form

- Log Y = f(M) + f(D) + f(S)
  - $>$ f(M) = a + b_1M + b_2M^2 [Source term]
    - a = a_1U + a_2RR + a_3SS [focal mechanism dependence]
  - $>$ f(D) = (c_1 + c_2M)*logR + c_3(R − R_0) [Path term]
    - R = sqrt (R_{epi}^2 + h^2), h = 10 km
    - R_0 = 1 km
  - $>$ f(S) = $d_1$$S_s$ + $d_2$$S_d$ [Site term − 3 site categories]
- Two Stage Regression
  - 1st: distance and site, determining event terms
  - 2nd: magnitude and focal mechanism

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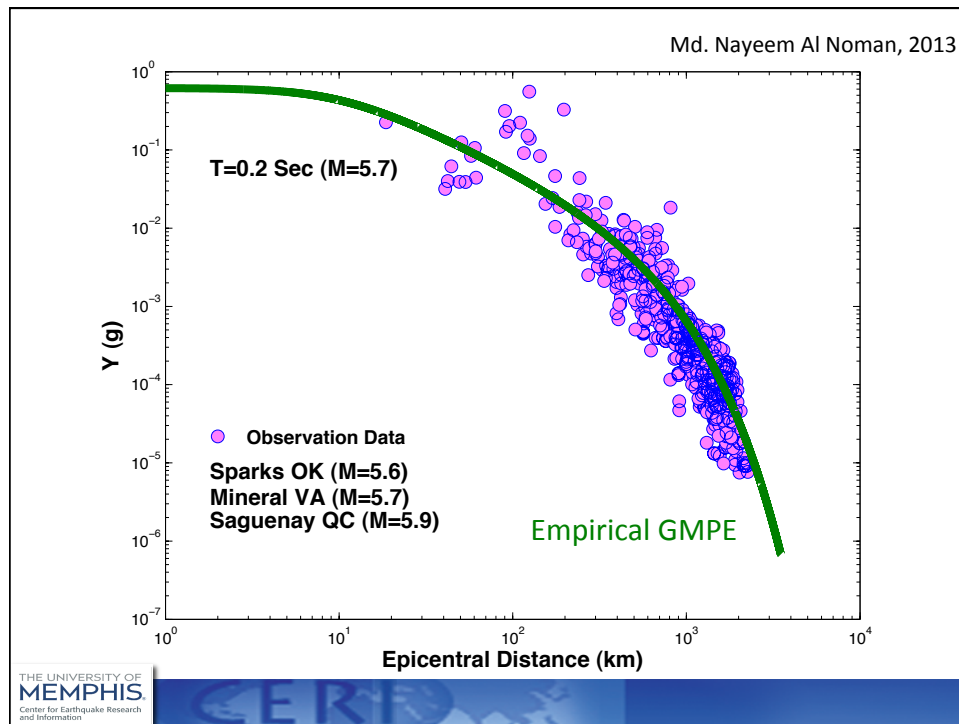
Conclusions

- Developed a new database of ENA ground motions containing over 10,000 records (1 to 3 component)
- Records processed in a uniform manner and QA'd
- Limited observations above M6.0 and within 100 km, but much improved from a decade ago
- Database useful for model bias residual analysis, Q estimation, and GMPE development, including an empirical GMPE for ENA