NGA-Subduction Research Program

Yousef Bozorgnia\(^{(1)}\)
As part of NGA-Subduction Research Group

\(^{(1)}\) UCLA Department of Civil and Environmental Engineering and Garrick Institute for the Risk Sciences
Outline

• NGA-Sub database
• Scope and status of NGA-Sub ground motion models
• Summary
The project has 33 contributors

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Acknowledgements

Supports of the following agencies are gratefully appreciated:

• FM Global
• USGS
• Caltrans
• PG&E
NGA-Sub database

• The database span:
  – **1,880** worldwide events
  – **71,340** three-component recordings
  – Over **214,020** records
  – Over 6,000 recording stations
  – Magnitudes from 4 to 9.1
  – Interface, Intraslab ("slab") classifications

This is the largest database among all NGA programs
NGA-Sub database

- The database includes:
  - Acceleration, velocity & displacement time series
  - Pseudo-spectral acceleration (PSA) for periods: 0.01-10 sec
  - For 11 damping values between 0.5% and 30%
    - We will expand to 70% damping ratio
  - Fourier amplitude spectra (FAS) for frequencies from 0.1 to 100 Hz
  - Significant durations based on Arias Intensity
NGA-Sub database: Event distribution

• Database includes events and ground motions recorded since early 1970s to present, including recent significant earthquakes:
  – 2010 Maule, Chile (M8.8)
  – 2011 Tohoku, Japan (M9.1)

• Database includes more data than any previously compiled databases (e.g. BCHydro 2016)
NGA-Sub database: M-R distribution
NGA-Sub database: M-R distribution

Epicentral Distance (km)

Magnitude

Japan
Taiwan
Pacific Northwest
Alaska
South/Central America

2011 Tohoku, Japan
2010 Maule, Chile
Alaska
Pacific Northwest
Taiwan
Worldwide epicenters and recording stations

[Map showing worldwide epicenters and recording stations with labels for Epicenters and Stations]
Distribution of records, events and stations

a) Total Number of Records = 71340

b) Total Number of Events = 1880

c) Total Number of Stations = 6433
Modelers can select a subset of data for their analysis: An example of selected recordings
NGA-Sub: Relational database

Metadata:
• Source
• Site
• Path
• Event Class

Data:
• Peak GM values
• PSA
• Duration
• FAS
NGA-Sub flatfile and time series

- All data have been stored & managed in a relational database
  - Relational database will improve update and expansion
  - Relational database can be queried by other databases, such as NGL (liquefaction)
- Time series of NGA-Sub:
  - About 500 time series were selected and released to the public
NGA-Sub Ground Motion Models

- **Scope:**
  - GMMs for horizontal components of ground motions
    - Vertical GMMs may be developed in 2020
  - 5%-damped PSA for T=0 to 10 sec
  - Interface: Magnitude range 5.0- 9.5
  - Slab: Magnitude range 5.0- 8.5
  - Rrup: 10 – 1000km
  - Ztor:
    - Interface: < 50 km
    - Slab: < 200 km
  - Vs30: 150-1500 m/sec
NGA-Sub Ground Motion Models

- There are “Global” and Regionalized models
  - Two global and regionalized models are final and reports are being published
    - Kuehn-Bozorgnia-Campbell-Gregor
    - Parker-Stewart-Boore-Atkinson-Hassani
  - One more global and regionalized model is being finalized
    - Abrahamson-Gulerce
  - Two Japan-specific models are final and reports are being drafted
    - Si-Midorikawa-Kishida
    - Youngs-Chiou-AlAtik
NGA-Sub Ground Motion Models

- Seven regions are considered
  - Alaska (AK)
  - Central America and Mexico (CAM)
  - Cascadia (CASC)
  - Japan (JP)
  - New Zealand (NZ)
  - South America (SA)
  - Taiwan (TW)
NGA-Sub Ground Motion Models

- Heavy focus on regionalization (or lack of regionalization) on terms, including:
  - Vs30 scaling
  - Anelastic attenuation
  - Regional effects of amplification (constant term)
  - Regionalized magnitude scaling for slab & interface events (some models)
**General characteristics of GMMs (besides regionalization)**

- Interface and slab geometrical spreadings are different
- Interface and slab anelastic attenuation is the same
- Interface and slab magnitude scaling below the break point are different
- Slope of mag scaling beyond break point is the same for slab and interface
- Some models: Forearc-backarc are for Japan, Central and South America
- Some models: Basin effects are for: Japan, Cascadia (Z2.5); Taiwan and NZ (Z1.0)
Break in magnitude scaling

- Investigation by UC Santa Barbara researchers for “Slab” events:
  - Break point in magnitude scaling for in-slab events is a function of the slab thickness. This feature is being incorporated into ground motion models
- Campbell generalized it for Interface events
Example of Break in magnitude scaling for In-Slab events

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<tr>
<th>Subduction Zone</th>
<th>Saturation Magnitude</th>
<th>Fault Maximum Width</th>
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<td>Aleutian</td>
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<td>Alaska</td>
<td>7.2</td>
<td>22.5</td>
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<td>Central America South</td>
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<td>Central America North</td>
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<td>Taiwan</td>
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NGA-Sub Ground Motion Models: Cascadia

• Special attention on Cascadia:
  • No recorded large magnitude interface event in the region
  • Few in-slab events. Most of them have lower motions than global model
  • Thus, if you do “purely statistical” analysis of small magnitude in-slab events, you get much lower prediction of motion in Cascadia
  • NGA-Sub did major, multiple, internal discussions on modeling for Cascadia
Cascadia events before regionalization

- 2010 Ferndale EQ; M6.55
- 2001 Nisqually EQ; M6.8
Cascadia events after regionalization
Assumptions for Cascadia GMMs

• **Slab**: Model constant is calculated from two largest all events (Nisqually and Ferndale). This leads to a somewhat increase in prediction compared to all Cascadia events

• **Interface**: No recorded interface events. Interface constant is determined by correlation between interface and slab constants globally

• **Slab and Interface**: Anelastic attenuation and Vs30-scaling for Cascadia are the same for interface and intraslab, and are determined from all events in Cascadia
Basin effects in Seattle: An example (KBCG model)

Interface Cascadia: M8, Rrup=100km, Vs30=400m/s, Z25=7km

- Unity
- KBCG (Z25=7km/Z25=1.34km)
- KBCG-Seattle Basin
Possible In-Model Epistemic Uncertainty
Epistemic uncertainty of median prediction

Example: $M = 6$, $R_{rup} = 100$ km, $V_{s30} = 400$, $Z_{TOR} = 10$ km, Interface and Forearc
Example results

![Graphs showing seismic response spectra for Cascadia interface and slab scenarios.](image-url)
**Summary and NGA-Sub status**

- Two global and regionalized models are final
  - They include basin effects
  - They include Cascadia and Alaska as regions
  - Reports to be published in February 2020
- One more global and regionalized model is being finalized
- Two Japan-specific GMMs are being finalized and documented
- Two other reports will be published in Feb 2020:
  - Database report
  - Comparisons of NGA-Sub GMMs and existing models
- Journal publications will follow the reports, to be submitted in 2020
- Damping scaling for NGA-Sub is being developed (Rezaeian, et al)
- Duration model for subduction is being developed (Walling-Kuehn-Abrahamson)
- CAV models are being developed (Macedo-Abrahamson, Campbell-Bozorgnia,...)
- Vertical GMMs for NGA-Sub may be developed in 2020 (depends on the funding)
Thank You
Example of epistemic uncertainty for magnitude scaling (Japan, Interface)
Standard deviation of median prediction (epistemic) for each region (M = 6, RRUP = 100 km, VS30 = 400, ZTOR = 10 km, Interface and Forearc)
Attenuation of Interface and slab events