# NGA-Subduction Research Program

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**As part of NGA-Subduction Research Group**

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The B. John Garrick Institute for the Risk Sciences
UCLA ENGINEERING

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# Outline

- NGA-Sub database
- Scope and status of NGA-Sub ground motion models
- Summary

# The project has 33 contributors

| | | | |
|---|---|---|---|
| 1 | Norm Abrahamson | 18 | Nicolas Kuehn |
| 2 | Sean Ahdi | 19 | Dong Youp Kwak |
| 3 | Tim Ancheta | 20 | Annie Kwok |
| 4 | Ralph Archuleta | 21 | Po-Shen Lin |
| 5 | Gail Atkinson | 22 | Harold Magistrale |
| 6 | David Boore | 23 | Sanaz Rezaeian |
| 7 | Yousef Bozorgnia | 24 | Silvia Mazzoni |
| 8 | Ken Campbell | 25 | Sifat Muin |
| 9 | Brian Chiou | 26 | Saburoh Midorikawa |
| 10 | Victor Contreras | 27 | Grace Parker |
| 11 | Robert Darragh | 28 | Hongjun Si |
| 12 | Nick Gregor | 29 | Walter Silva |
| 13 | Zeynep Gulerce | 30 | Jon Stewart |
| 14 | I.M. Idriss | 31 | Melanie Walling |
| 15 | Chen Ji | 32 | Katie Wooddell |
| 16 | Ronnie Kamai | 33 | Bob Youngs |
| 17 | Tadahiro Kishida | | |

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# Acknowledgements

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- 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**

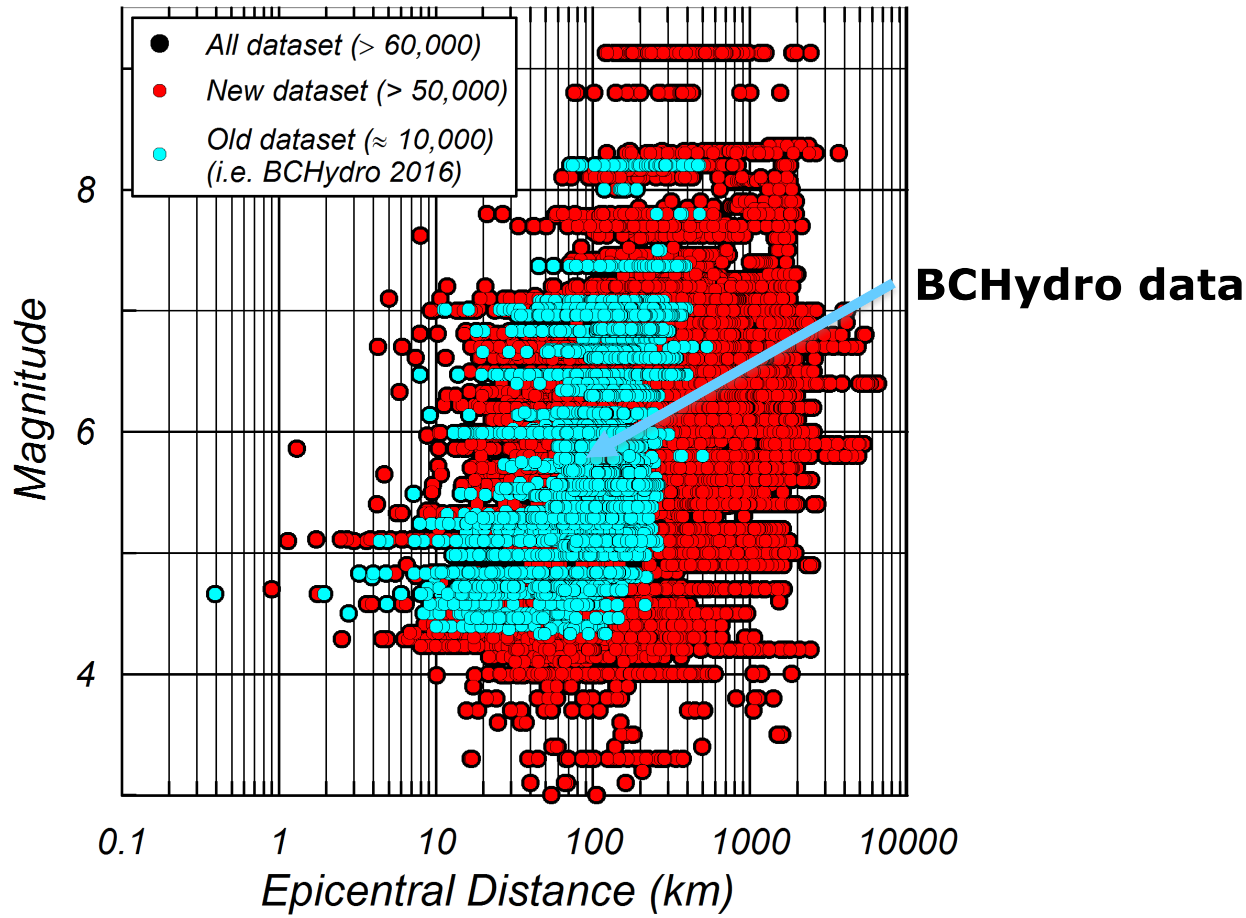
# NGA-Sub database

- 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

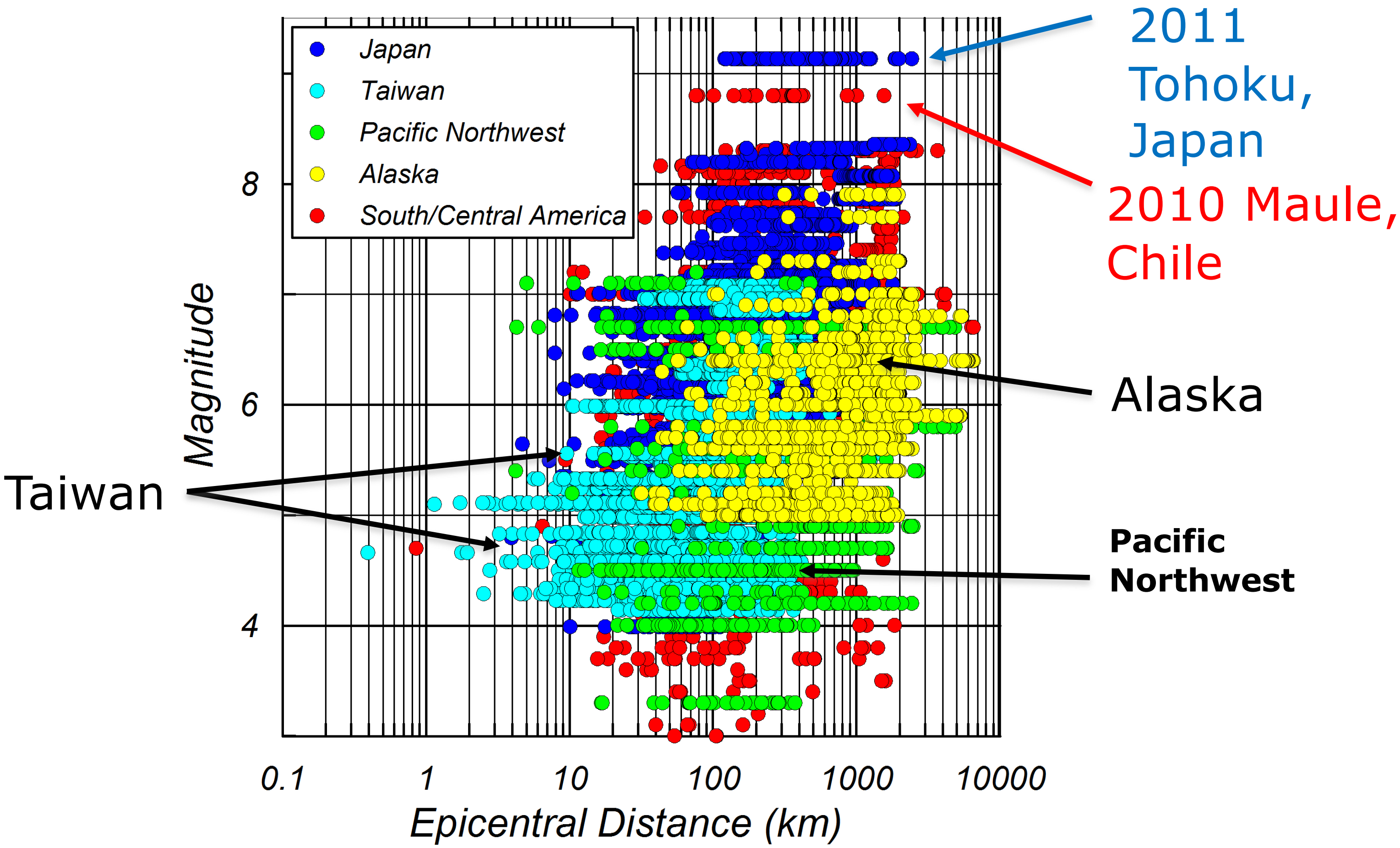
# NGA-Sub database: Event distribution

- 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)

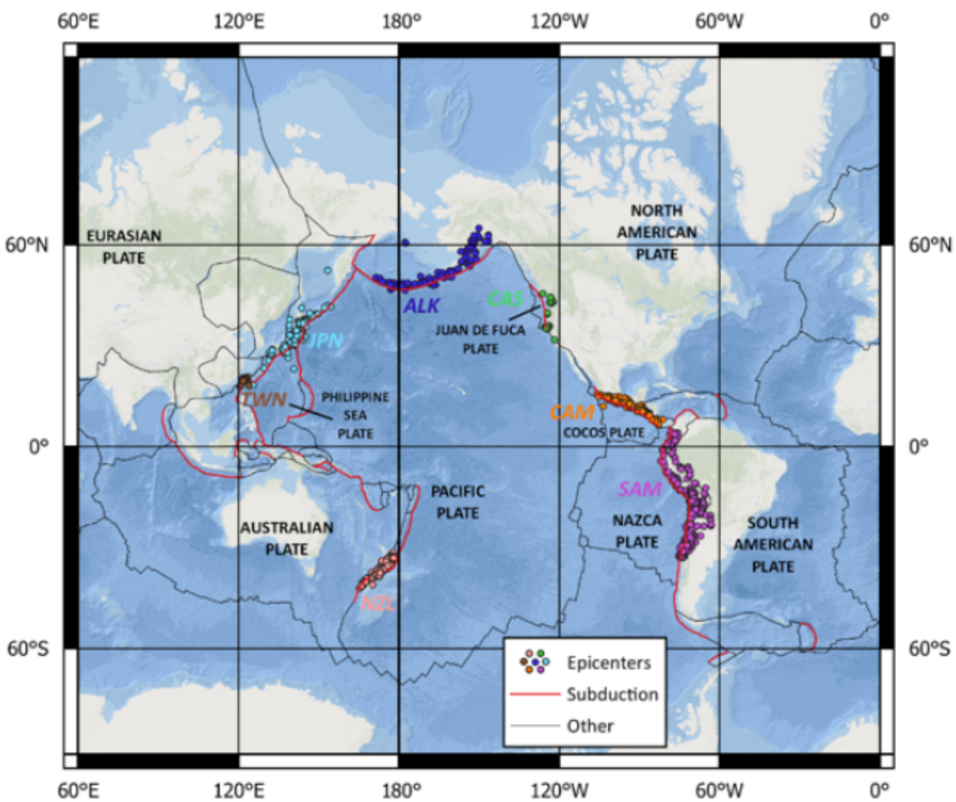
# NGA-Sub database: M-R distribution



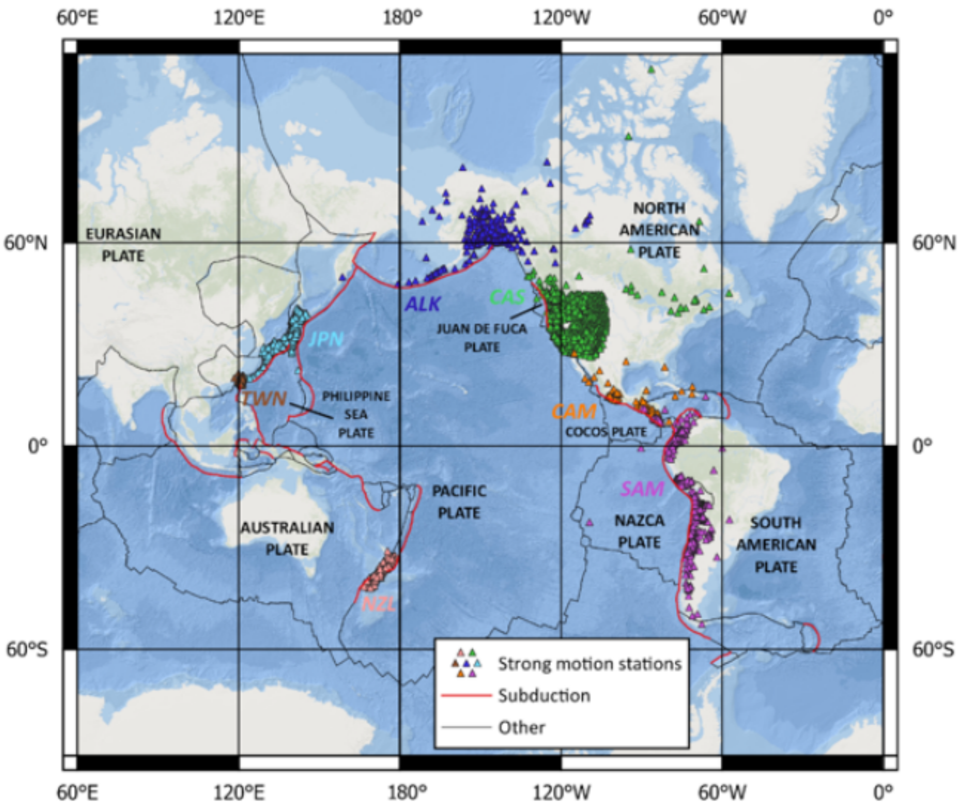
# NGA-Sub database: M-R distribution



# Worldwide epicenters and recording stations

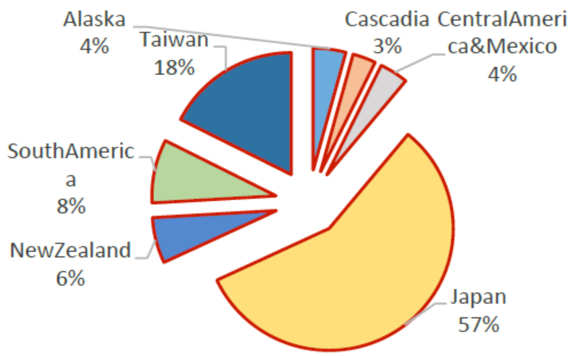



Epicenters

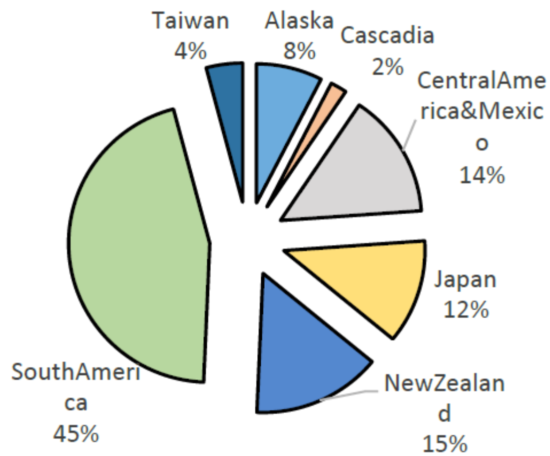



Stations

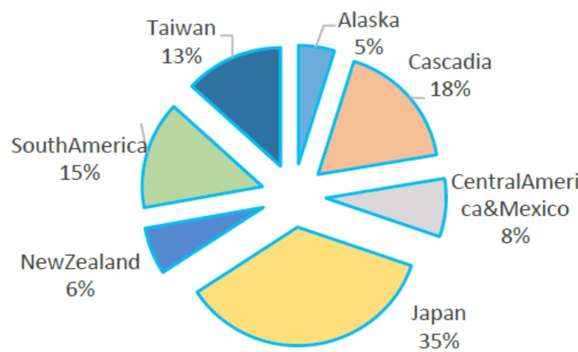
# Distribution of records, events and stations




a) Total Number of Records = 71340

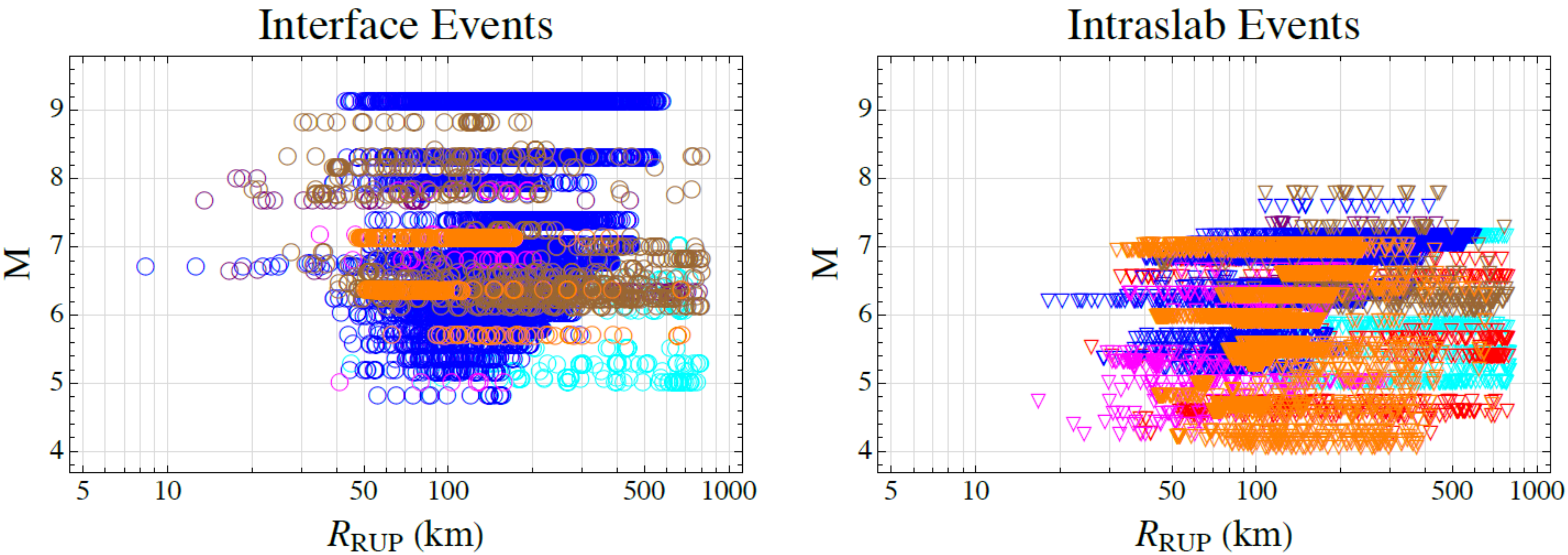



b) Total Number of Events = 1880




c) Total Number of Stations = 6433

# Modelers can select a subset of data for their analysis: An example of selected recordings



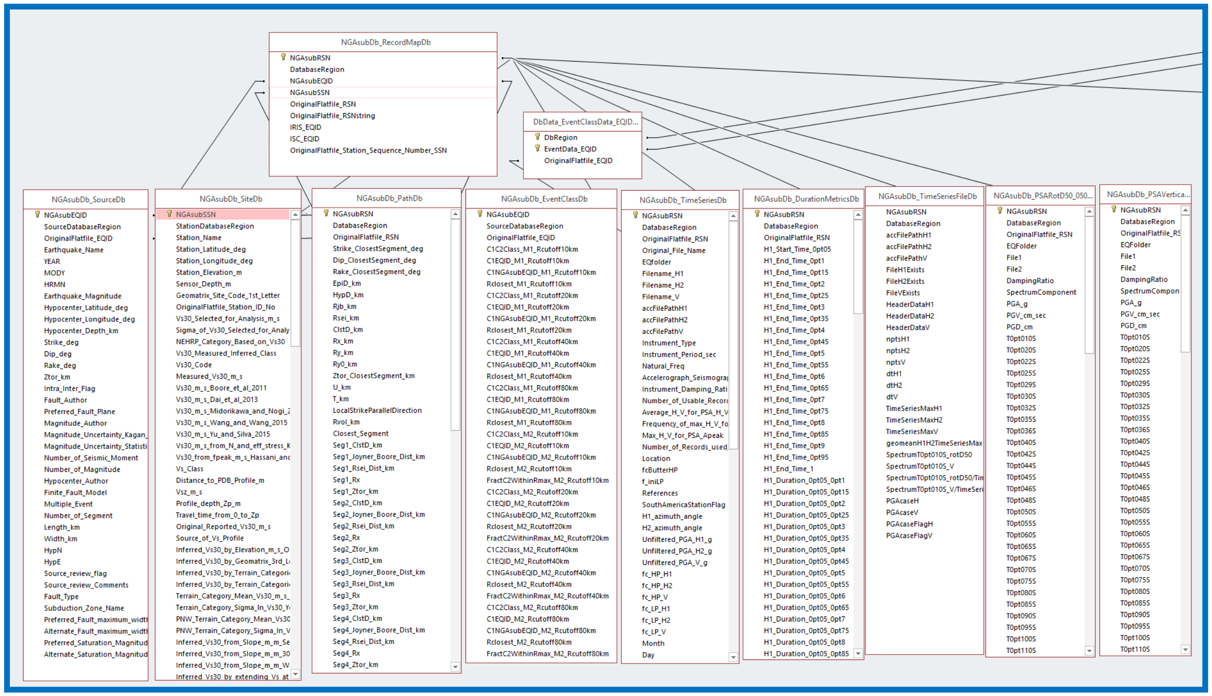
# NGA-Sub: Relational database

**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

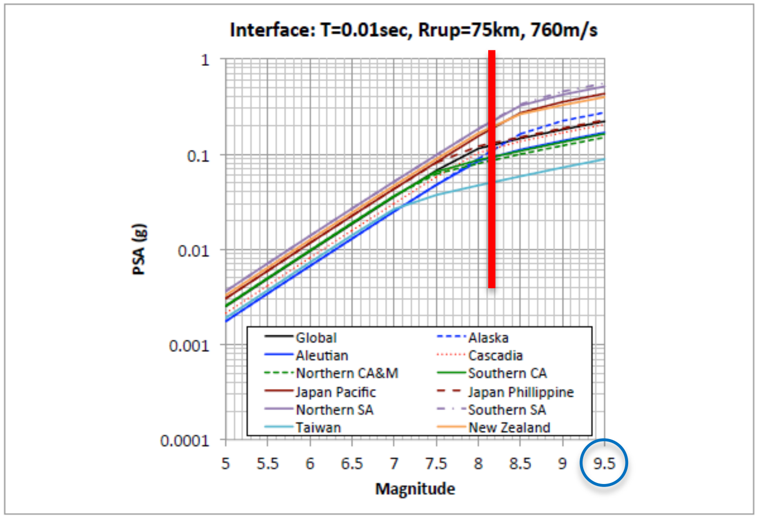
- Heavy focus on regionalization (or lack of regionalization) on terms, including:
  - Vs30 scaling
  - Anelastic attenuation
  - Regional effects of amplification (constant term)
  - Regionalized magnitude scaling for slab & interface events (some models)

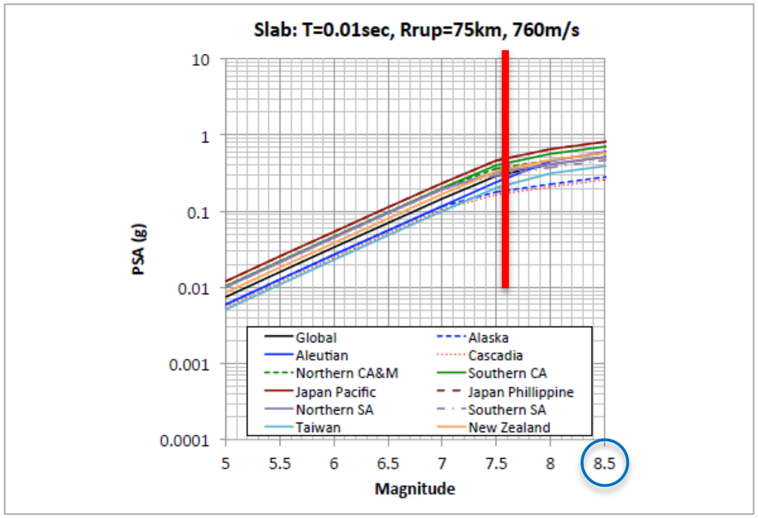
## General characteristics of GMMs (besides regionalization)

- 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



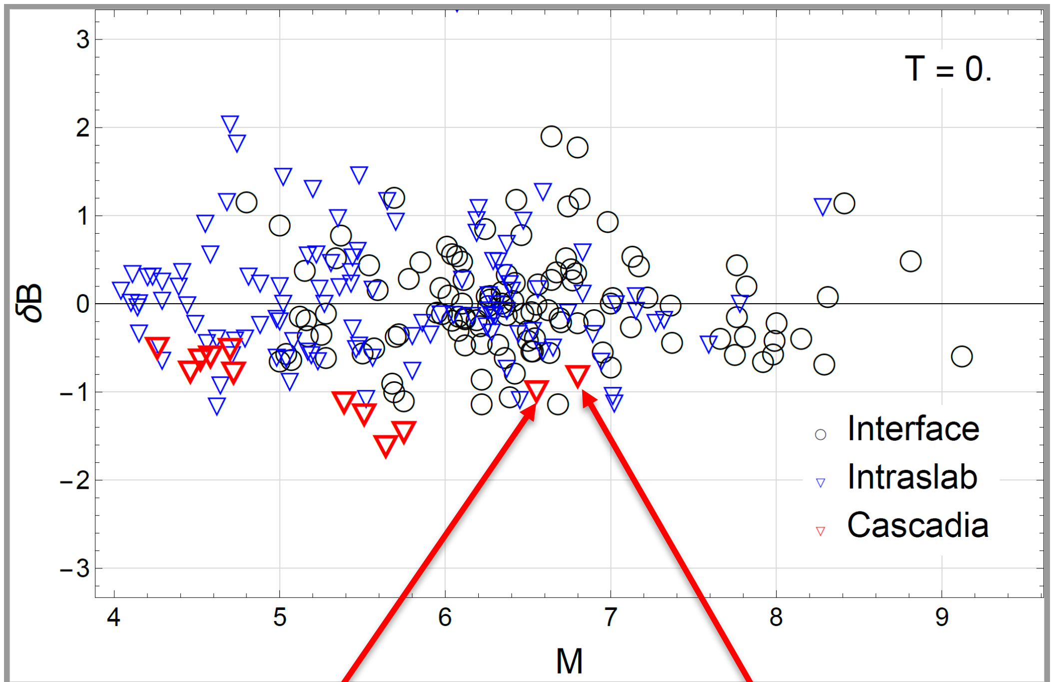
# Example of Break in magnitude scaling for In-Slab events

| Subduction Zone | Saturation Magnitude | Fault Maximum Width |
|---|---|---|
| Aleutian | 7.95 | 53 |
| Alaska | 7.2 | 22.5 |
| Cascadia | 7.2 | 22 |
| Central America South | 7.6 | 36 |
| Central America North | 7.4 | 28 |
| Japan Pacific | 7.65 | 38.5 |
| Japan Philippines | 7.55 | 36 |
| New Zealand North | 7.6 | 37.5 |
| New Zealand South | 7.4 | 30.5 |
| South America North | 7.3 | 25 |
| South America South | 7.25 | 24 |
| Taiwan | 7.7 | 42 |

# 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

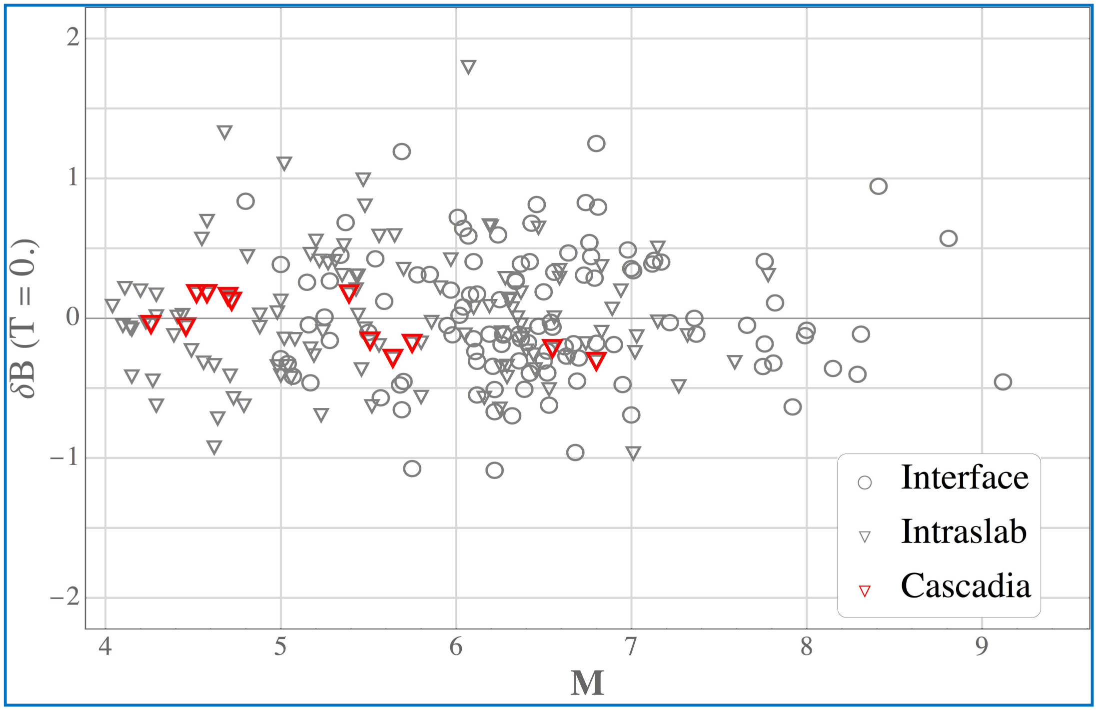
# Cascadia events before regionalization




2010 Ferndale EQ; M6.55

2001 Nisqually EQ; M6.8

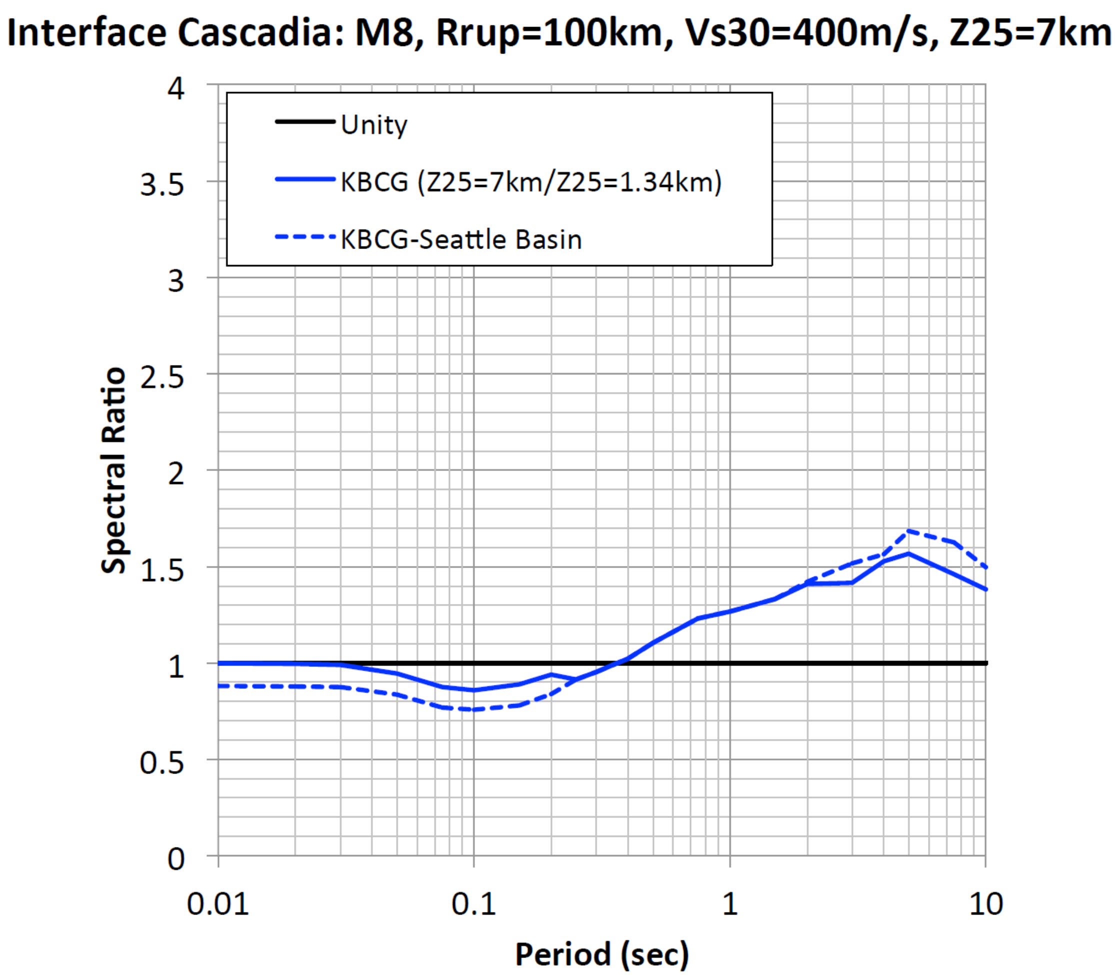
# Cascadia events after regionalization



# Assumptions for Cascadia GMMs

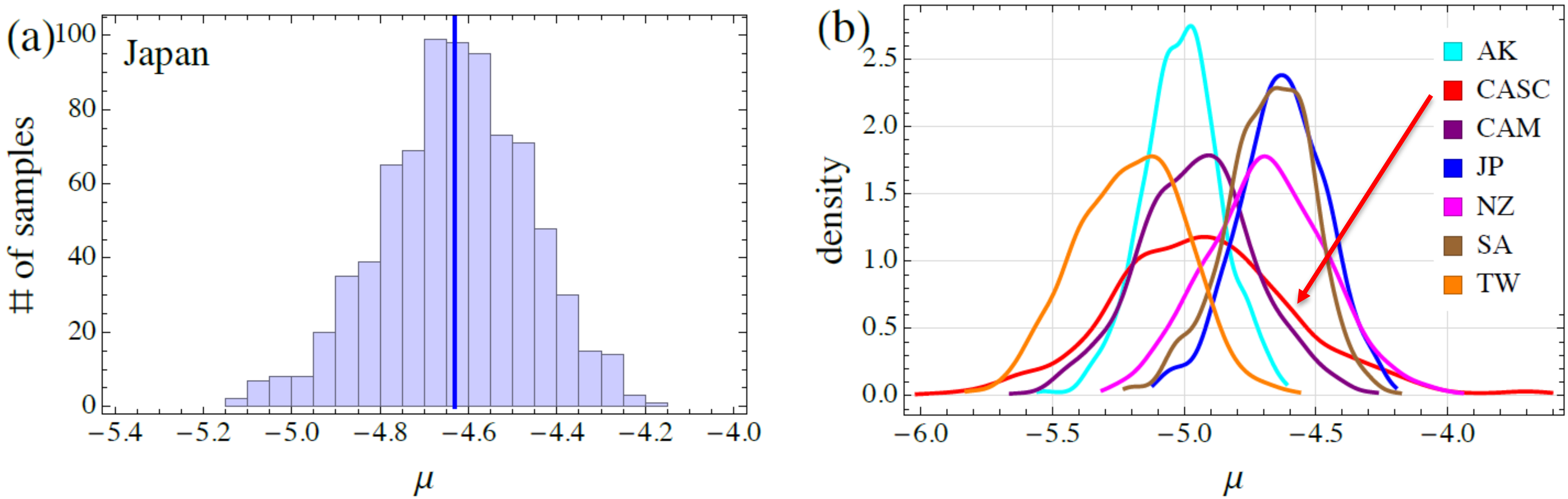
- **Slab**: Model constant is calculated from two largest all events (Nisqually and Ferndale). This leads to a somewhat increase in prediction compared to all Cascadia events
- **Interface:** No recorded interface events. Interface constant is determined by correlation between interface and slab constants 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)



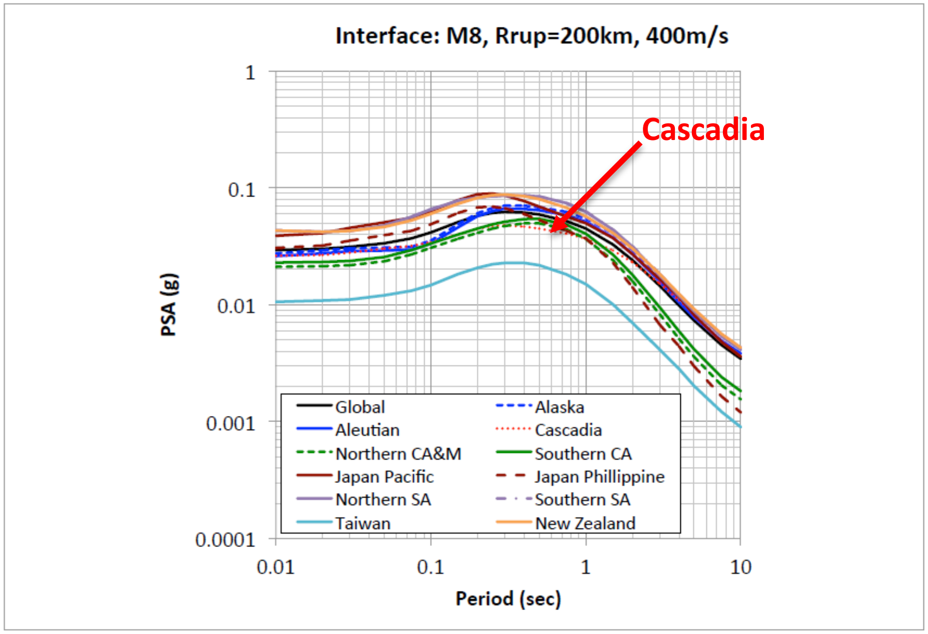
# Possible In-Model Epistemic Uncertainty

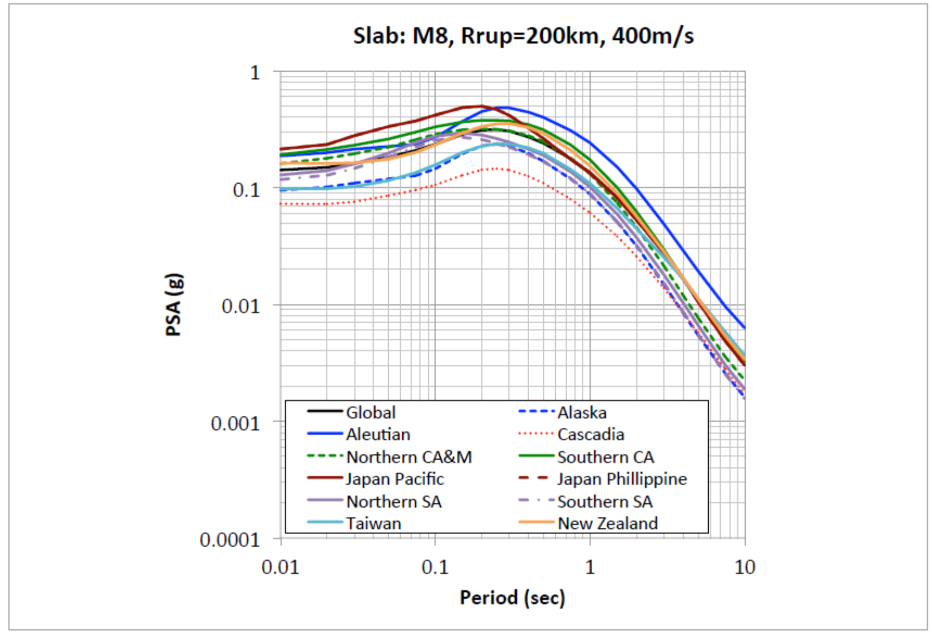
# Epistemic uncertainty of median prediction




Example: M = 6, Rrup = 100 km, Vs30 = 400, ZTOR = 10 km, Interface and Forearc

# Example results



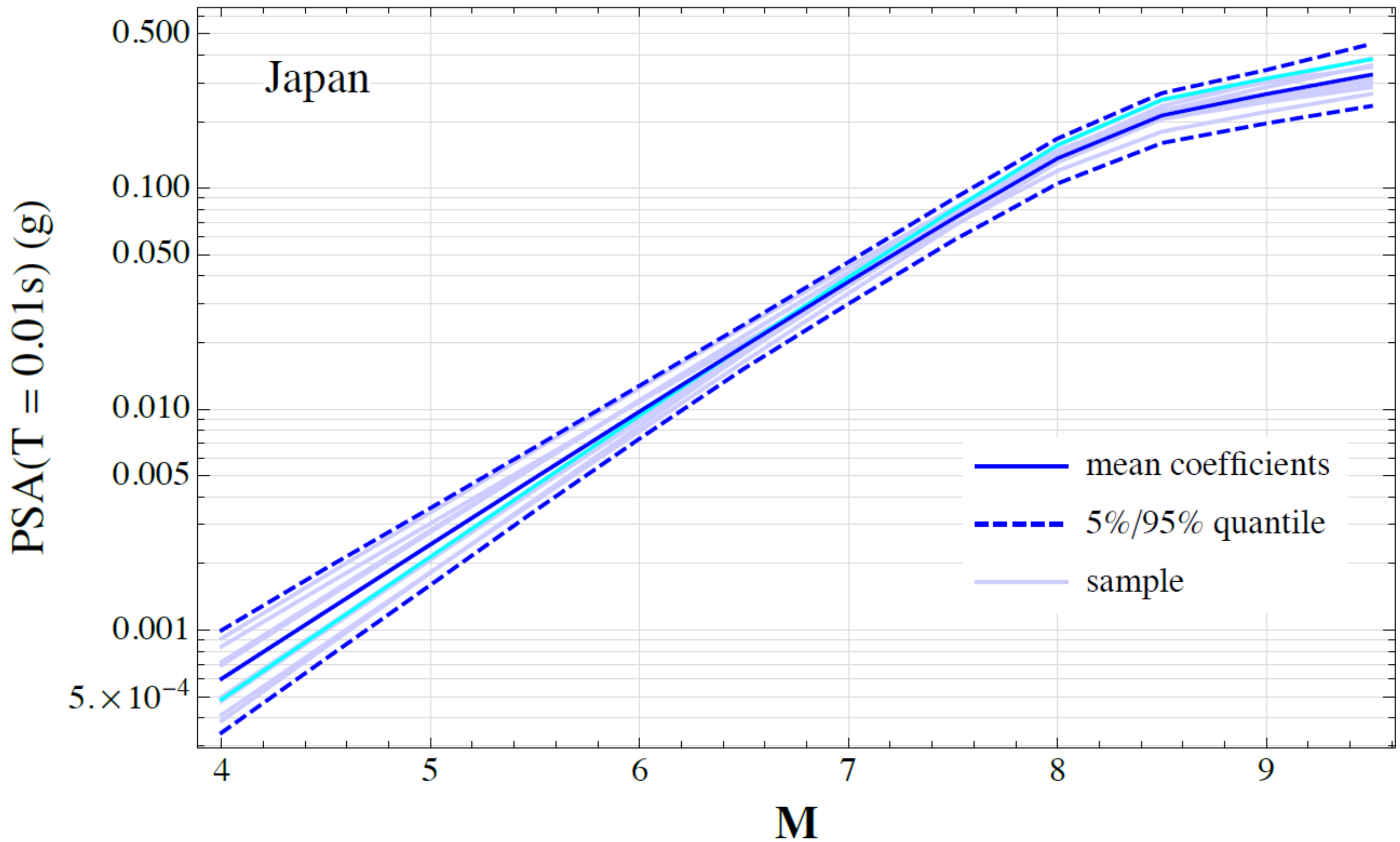



# Summary and NGA-Sub status

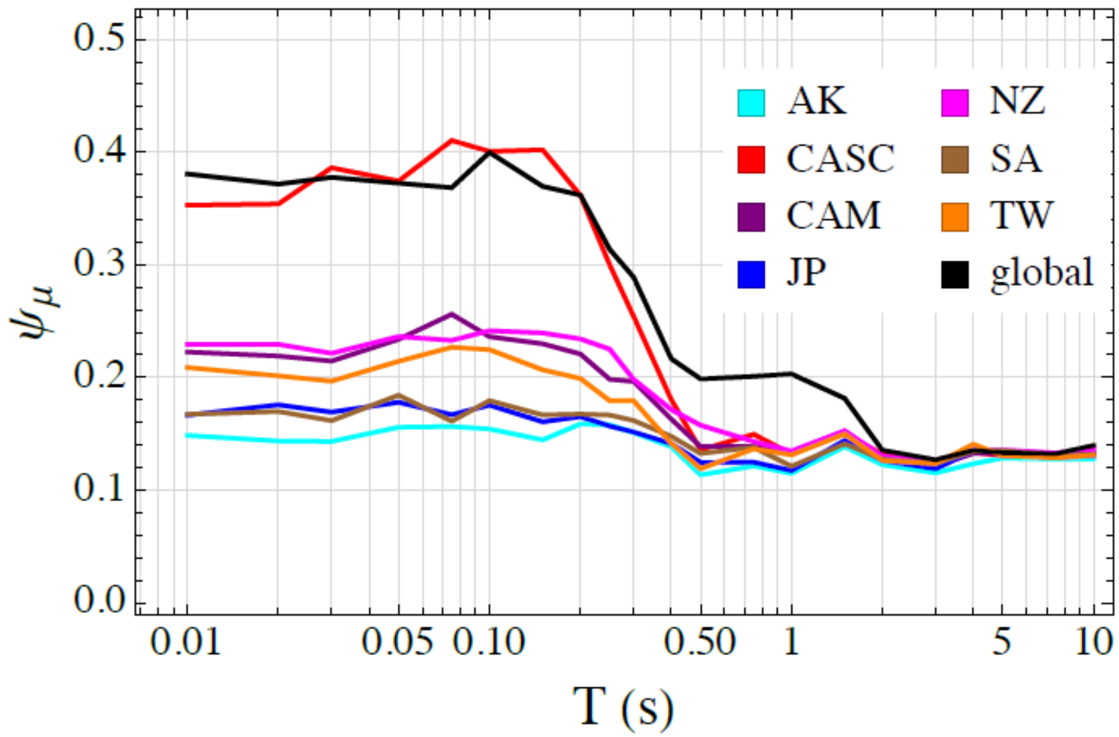
- Two global and regionalized models are final
  - They include basin effects
  - They include Cascadia and Alaska as regions
  - Reports to be published in February 2020
- One more global and regionalized model is being finalized
- Two Japan-specific GMMs are being finalized and documented
- Two other 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