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Resilience Through Community Engagement and Technology

Summary of the NGA-West3 Project Database

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ABSTRACT

The Next Generation Attenuation (NGA)-West3 Program database builds upon that of NGA-West2 for shallow crustal earthquakes in active tectonic regimes to provide a robust dataset to develop the next iteration of NGA ground motion models (GMMs). Researchers from Italy, Japan, New Zealand, Taiwan, United Arab Emirates, and the United States, amongst others, have collaborated to develop consistently processed data with uniform metadata from the respective regions, with data for other regions drawn from literature (e.g., Greece, Japan, Türkiye). Over 150,000 three-component ground motions (mostly in California and Japan) with magnitudes generally greater than 3.0 have been newly added and the total database size is over 175,000 ground motions (generally three-component except for two-component records from KiK-Net stations in Japan). The database is being used by several teams of NGA GMM developers.

Introduction

NGA-West3 is one in a series of Next Generation Attenuation (NGA) projects directed towards database and ground motion model development for applications in seismic demand characterization, and represents the third phase of programs targeting shallow-crustal earthquakes in active tectonic regimes. The NGA-West3 database contains 175,244 (mostly) three-component records from 7,304 earthquakes from eight global regions. These data were processed on a component-specific basis to maximize usable bandwidth of the data and to remove baseline drifts. The majority of new data were processed using a semi-automated approach, which is new to NGA projects. Various ground motion intensity measures were computed including peak acceleration, peak velocity, pseudo-spectral accelerations for a range of oscillator periods, effective amplitude spectra for a range of frequencies, cumulative absolute velocity-parameters, Arias intensity, and measures used to compute significant durations. This article provides a brief summary of the NGA-West3 project database, and differs specific details to [1].

Global Regions

Data collection as part of the NGA-West3 project targeted events in Western North America (WNA: US, Canada, and Mexico), Greece, Iran, Italy, Japan, New Zealand, Taiwan, and Türkiye. Some of these data were adopted from prior work, including: several data-collection efforts in California ([2], [3], [4], [5], [6], and [7]), the Hellenic Strong-Motion Database in Greece [8], the Italian Accelerometric Archive (ITACA) ([9] and [10]), ground motions from the 2023 Kahramanmaraş, Türkiye earthquake sequence [11], a database of earthquake ground motions in Iran [12], a database of KiK-Net records in Japan [13], and the New Zealand Ground Motion Database (NZGMDB) [14]. During NGA-West3, considerable effort went into expanding ground motion data resources in WNA, Greece, Japan, and Taiwan.

Database Statistics

Fig. 1 shows the distributions of ground motions, events, and stations within the NGA-West3 database differentiated by region. The proportion of events in WNA relative to the overall database is relatively modest (13.8%), but the proportion of stations is relatively high (43.2%). The combination of these factors is responsible for WNA contributing the majority of ground motion data (54.7%), which are dominated by earthquakes in California (82.6% of all WNA ground motions). Events in Japan contributed the second most number of ground motions (28.1%), even though there are proportionally fewer stations (17.6%) because there are more events (29.0%). The representation of the number of events in Iran (43.7%) is disproportional to the number of ground motions (3.5%) even though the number of stations is similar to other regions (e.g., Italy and Türkiye). This is because most of the events in Iran are poorly-recorded, small-magnitude earthquakes (i.e., few observations per event). The contributions of ground motions from events in Greece, Italy, Taiwan, and New Zealand are very similar (2.0 ~ 3.5%), even though the numbers of events and stations exhibit greater variability (0.3 ~ 6.0% for events; 2.7 ~ 8.5% for stations). Very few events in Türkiye were added as part of NGA-West3, however those that were added are large-**M** strike-slip events with many recordings. Events in Türkiye make up only 1.0% of the total number of events, whereas they contributed 1.2% of the total ground motion records.

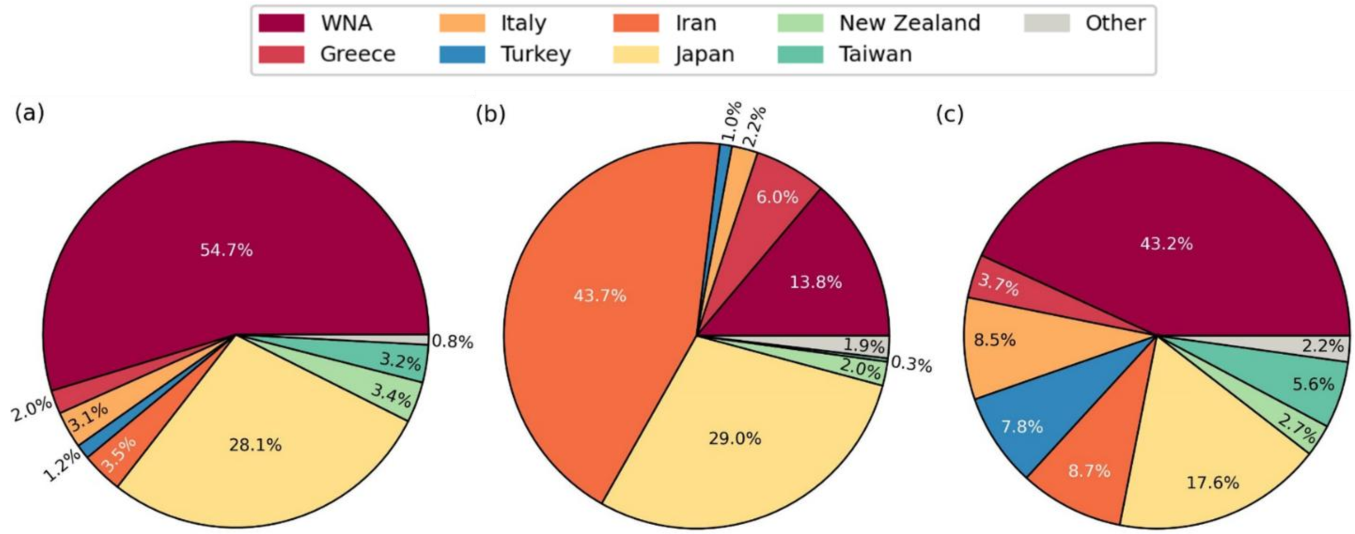

Figure 1. Regional distributions of (a) ground motion records, (b) events, and (c) stations in the NGA-West3 database.

Overall Database

Fig. 2 presents the distributions of ground motion records with respect to magnitude (**M**) and closest distance to the rupture surface (R_{RUP}). The range of **M** included in the NGA-West3 database is **M**1.05 to **M**7.9. The majority of data are associated with moderate-**M** events (4.0 ≤ **M** ≤ 5.0), however there is increased representation of large-**M** (**M** ≥ 6.5) events compared to previous iterations of NGA-West. Most data were recorded at larger distances (e.g., 80 km ≤ R_{RUP} ≤ 400 km), although there are many near-field observations (R_{RUP} ≤ 15 km), especially for large-**M** events.

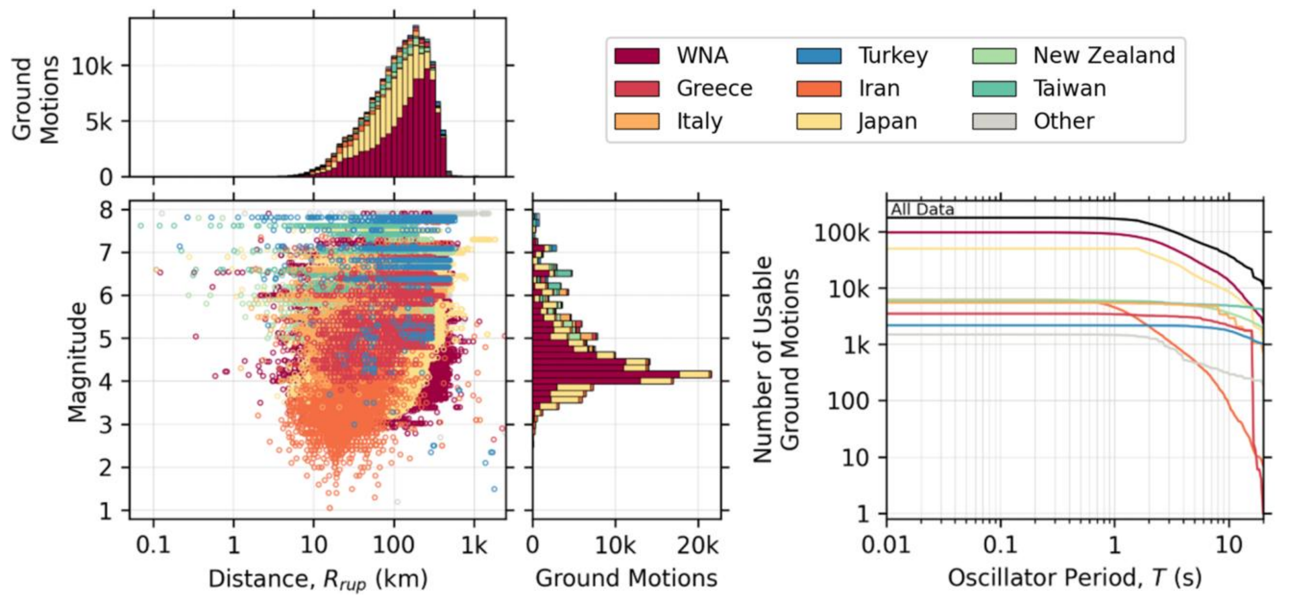

Figure 2. Distributions of ground motion records in **M** versus R_{RUP} space and number of usable ground motions per oscillator period for the overall NGA-West3 database.

Fig. 2 also shows the number of usable ground motions in the overall NGA-West3 database calculated as a function of oscillator period (for pseudo-spectral acceleration response spectra; *PSA*). The global database includes 175,244 records, for which most *PSA* ordinates are usable at periods shorter than ~2 s. This number significantly decreases for longer periods because most records are associated with small-to-moderate **M** events (**M** < 5.0) (i.e., less energy at long periods, which in turn increases the likelihood that such components of the record will be noise-dominated). Only 38,313 (21.9%) records have usable *PSA* at periods longer than 10 s. In the frequency domain, most records are usable between 0.5 to 10 Hz, however only 38,431 (21.9%) records can be used at frequencies less than 0.1 Hz and 14,109 (8.1%) records can be used at frequencies higher than 50 Hz.

Fig. 3 presents pixel maps of peak ground acceleration (*PGA*) for the RotD50 horizontal component as defined by [15] versus **M** and R_{RUP}. Pixels are colored based on the number of records that plot within each pixel's coverage area. The range of *PGA* is 2.6×10^{-7} to 2.4 g, with larger amplitude records generally associated with larger-**M** events and/or shorter R_{RUP}. Since the majority of ground motions are associated with moderate-**M** events ($4.0 \leq$ **M** ≤ 5.0) and far distances ($R_{RUP} \geq 80$ km), most *PGA*s are between 10^{-5} to 10^{-2} g. Overall, there are 4,485 (2.6%) records with RotD50 *PGA* ≥ 0.1 g and 260 (0.2%) records with RotD50 *PGA* ≥ 0.5 g.

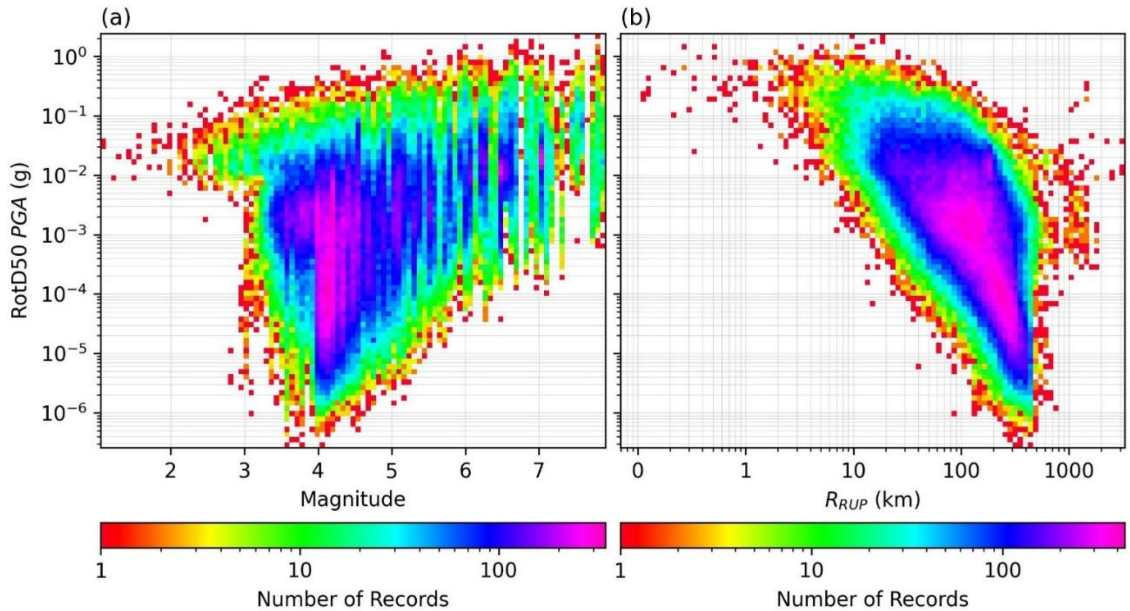

Figure 3. Pixel maps of *PGA* for the RotD50 horizontal component versus (a) **M** and (b) R_{RUP} for the overall database. Pixels are colored based on the number of records within their coverage area.

Summary

A key feature of the NGA-West3 database is the substantial increase in the volume of ground motion data, which includes recordings from recent significant earthquakes and previously underrepresented regions. Newly added data significantly expand the number of records over a wide range of **M**, R_{rup}, and site conditions compared to the previous NGA databases. The greatest increase of data is observed for $3.5 \leq$ **M** ≤ 5.0 and $80 < R_{rup} < 300$ km. The greatest increases in data are coming from newly added events in Japan, northern Mexico, and the WUS, although much of these data are from small-to-moderate **M** events. Newly added data from Italy, New Zealand, Taiwan, and Türkiye are particularly beneficial because they are almost exclusively from larger **M** events (i.e., **M** ≥ 5.0), which are needed to help constrain GMMs for conditions that generally control hazard. [1] provides additional details about the database and its development, and the flatfiles are available at www.doi.org/10.34948/N3D30R**.**

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