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ABSTRACT

This paper summarizes a ground-motion database developed for the NGA-Sub Project. The database consists of two- and three-component ground-motion recordings from selected earthquakes in subduction zones. The database also includes the supporting data such as source, path, and site metadata. The earthquakes are located in Japan, Taiwan, the Pacific Northwest region of North America, Alaska, Mexico, Central and South America, and New Zealand. The events in the database are classified as interface, intraslab, or outer-rise, and have magnitudes ranging from 4 to 9. The database includes more than 71,000 three-component recordings, most of which are from digital accelerograms. The database includes PGA, PGV, pseudo-spectral acceleration for eleven damping values between 0.5% and 30%, Fourier amplitude spectra for frequencies from 0.1 to 100 Hz, and significant-shaking durations based on Arias Intensity. These data are analyzed in the project to model various ground-motion properties.

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Introduction

Uniformly-processed ground-motion data are essential for ground-motion studies. Next Generation Attenuation (NGA) ground-motion databases (e.g., http://ngawest2.berkeley.edu/, http://peer.berkeley.edu/ngaeast/) produced by the Pacific Earthquake Engineering Research Center (PEER) provide these data sets, which include time series and spectral data with associated metadata for selected earthquakes recorded in different tectonic settings and regions. Currently, the research program NGA-Sub is being conducted by PEER to develop data resources and ground-motion models (GMMs) for subduction-zone earthquakes [1]. The program is based on technical interactions among many individuals and organizations around the world. The database contains ~1,880 events from Japan, Taiwan, the Pacific Northwest region of North America, the state of Alaska in the United States, South America, Central America, Mexico, and New Zealand. More than 71,000 three-component time series are included from different data providers. The unprocessed waveforms were processed using a uniform set of instrument-correction, frequency filtering, and baseline-correction algorithms developed by PEER to obtain corrected acceleration time series, pseudo-spectral acceleration (PSA), Fourier amplitude spectra (FAS) and significant-shaking durations based on Arias Intensity (AI). These data are used to generate multiple new GMMs, which will significantly improve current models that rely on more limited data sets that encompass mainly moderate-magnitude events. This study describes the database including the supporting source, path, and site metadata.

Selected Earthquakes

Figure 1 plots the epicenter and station locations of all records in the NGA-Sub database. In the development of the database, we mainly collected and processed data from events having magnitudes greater than 5.0 by reviewing available catalogs such as the International Seismological Centre (ISC) website (http://www.isc.ac.uk/iscbulletin/search/catalogue/). Some relevant events with magnitudes less than 5.0 were also included for specific regions such as Chile based on data availability and quality. We collected and processed recordings mostly from digital instruments, but some important older analog records are also included. The time period covered by the database is from the late 1930s to the present, including recent significant earthquakes from 2016. More than 85% of the time series in the database were recorded after 2000. Figure 2 shows the distribution of the current database by region. The total number of three-component recordings, events, and stations are approximately 71,000, 1,900, and 6,100, respectively. Figure 2(a) shows that Japan and Taiwan provide the largest number of time series. Figure 2(b) shows that South America is the region with the largest number of subduction events. Figure 2(c) shows that Japan and the U.S. Pacific Northwest have the largest number of recording stations in the current dataset.

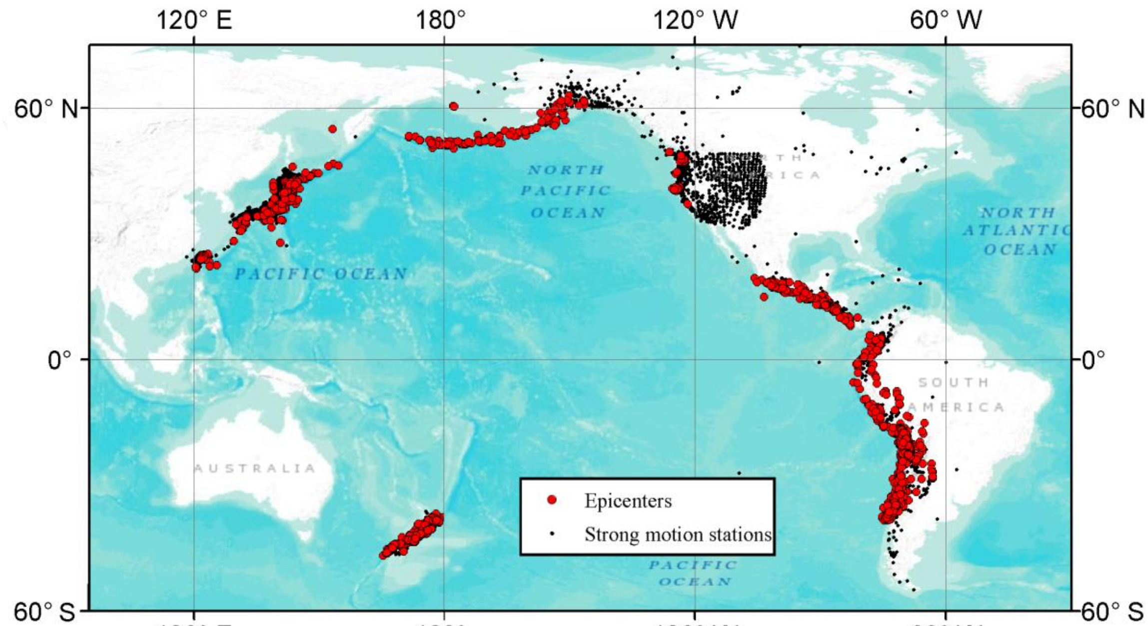

Figure 1. Epicentral and recording station locations in NGA-Sub database

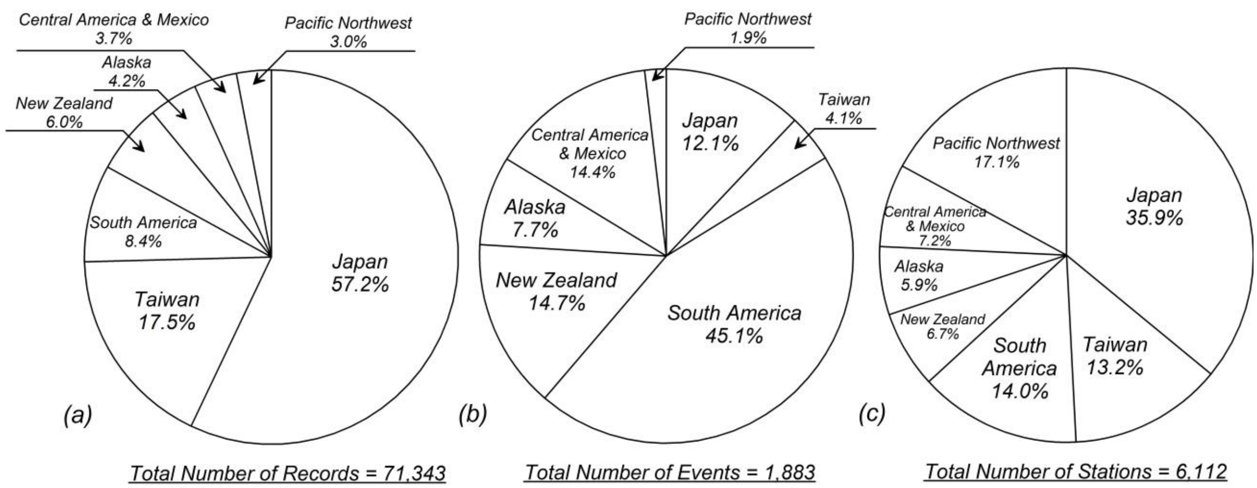

Figure 2. Regional distribution of the NGA-Sub database, (a) number of recordings, (b) number of events, (c) number of stations.

Database and Flatfile Overview

The NGA-Sub database consists of multiple component databases: a ground-motion database, an earthquake source database, and a site database. A "flatfile", which is a single summary data file used to develop GMMs, is generated by combining selected data from these component databases. This section provides an overview of these databases.

Ground Motion Database

More than 71,000 records have been processed and filtered following the standard PEER data-processing methods [2, 3] to provide uniformly-processed time series, PGA, PGV, PSA, FAS, and duration metrics in the ground-motion database. Instrument corrections were applied to the recorded time series in the frequency domain, as necessary. A time window for data processing was selected following the recommendations of previous studies [4, 5]. A 2% taper was applied to the start and end of the time window. An acausal Butterworth bandpass filter was applied after reviewing the FAS shape and the signal-to-noise ratio between the S-wave (or the entire time series) and the pre-event noise window (when available) on a component-by-component basis (e.g. [6]). PSA for 5% and other oscillator damping ratios, as well as FAS, were calculated at selected frequencies for all processed time histories following [3, 4]. The metadata from all the processing steps are also stored in the database including record starting time, location of station, time-window locations, and applied high-pass and low-pass filter corner frequencies. The processed data were also reviewed by visual inspection (e.g. late-P and -S triggered flag) and through residual analyses (e.g. PSA and FAS quality flags) as described in [3]. The largest distance is approximately 2,000 km to capture the attenuation of large-magnitude subduction events, which is useful in some regions. However, the largest distances depend on the region due to regional attenuation rates and station distributions. Figure 3 shows a scatter plot of recordings between magnitude and closest distance. Data distributions show that **M** and closest distance is positively correlated for all regions and that Japan, South America, Central America and Mexico are the only regions that include the events with **M** > 8.0.

Approximately 90% of the recordings are from accelerometers, while the remainder are from broadband seismometers. Table 1 shows the agencies that provided the time series used in the development of the database. For New Zealand recordings, we reviewed the processed time series published in [7], then directly adopted these records because selected high-pass and low-pass corner frequencies are consistent between [7] and the PEER data processing method. The agency names and acronyms are given in full in the acknowledgements section.

Table 1. Data resources of time series

Region	Agencies Providing Data
Japan	K-NET, KiK-net, PARI, JMA, NOAA, Hi-net
Taiwan	CWB, IES, K-NET
Pacific Northwest	CESMD, COSMOS, IRIS, NSMP, NCEDC, GSC
Alaska	CESMD, COSMOS, IRIS, GSC
South America	CESMD, COSMOS, NOAA, IRIS, GFZ, RENADIC, CSN, CISMID, NORSAR, RNAC
Central America and Mexico	NORSAR, CESMD, COSMOS, NOAA, IRIS, UNAM, MARN
New Zealand	GeoNet

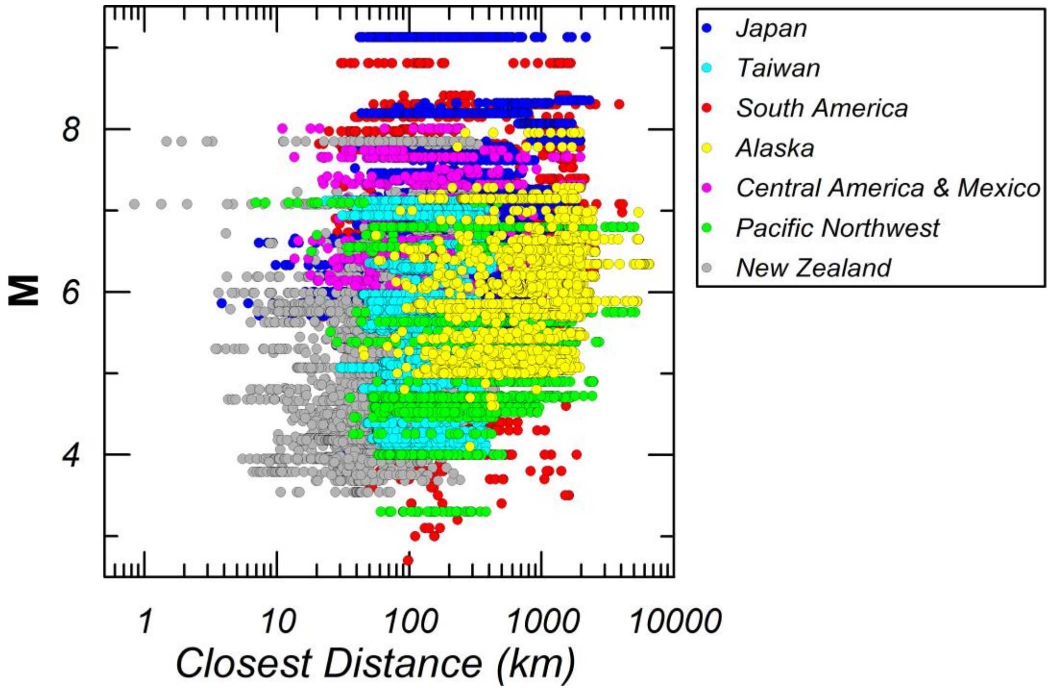

Figure 3. Scatter plot of closest distance versus magnitude

Earthquake Source Database

The earthquake source database consists of the event catalog and source parameters such as origin time, seismic moment (M_0), moment magnitude (**M**), hypocentral location and finite-fault attributes. The event catalog is developed by reviewing published catalogs (e.g. ISC catalog) and past studies (e.g. [8, 9, 10, 11]) with the inclusion of recent events. Regional studies and reports on subduction earthquakes were also reviewed along with interaction between multiple international experts to identify the earthquakes included in the dataset. Source parameters such as **M** and hypocentral locations are selected from several global and local data resources (e.g. [12, 13, 14]). The Global Centroid-Moment-Tensor catalog (GCMT) is given priority to determine **M**. Its standard deviations are also calculated when multiple moment-tensor solutions are available including special studies and source-inversion analyses. However, when **M** is not available, usually for smaller-magnitude earthquakes, the optimal estimate of **M** is determined from values of local magnitude (M_L), surface-wave magnitude (M_S), and body-wave magnitude (m_b) using correlations based on regional data.

Earthquakes have also been classified as either: interface, intraslab, outer-rise, or shallow crustal events by reviewing past studies and comparing hypocentral locations to available slab models for each region [15]. The mechanism of the events is defined using event rake angles, when available, aiming to be consistent with the earthquake classification. Figure 4 shows the event classification distribution in the database and indicates that interface and intraslab events are nearly evenly distributed. As a part of the earthquake source database, finite-fault models have been collected by reviewing past studies and several data resources (e.g. [13, 16, 17, 18]). More than 80 events have finite-fault models documented in the database, which covers about 35% of all records. Details of the methods to interpret and use these finite-fault models are described in [19]. Event classes (i.e. foreshock and aftershock flags) are also provided based on previous studies and the method described in [20].

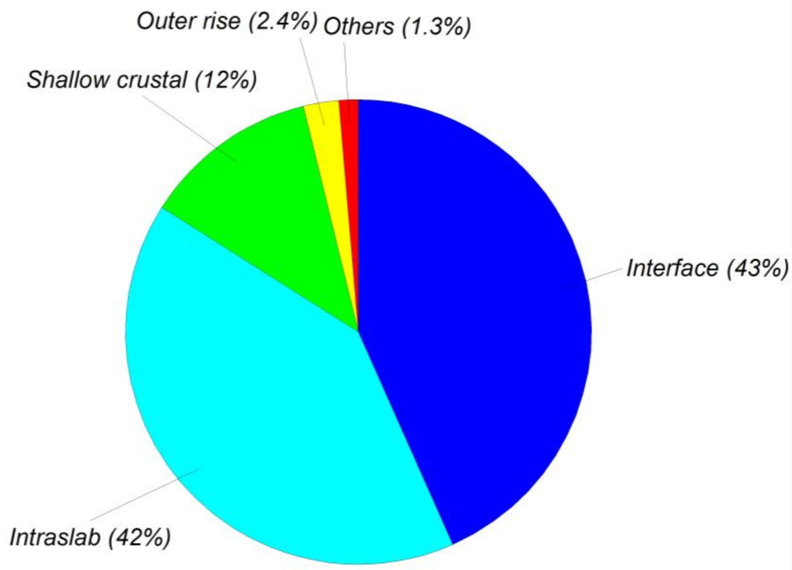

Figure 4. Distribution of event classification in the earthquake source database

Site Database

Approximately 6,100 stations are included in this database. The site database includes high-level metadata for each station, such as station name, station ID, recording network, geodetic coordinates, instrument location, and sensor depth. Information describing the soil profile characteristics of the site, such as the time-averaged shear-wave velocity (V_S) in the upper 30 m (V_{S30}) and depth to V_S horizons (Z_{xx}) to model basin effects are also included. The value of V_{S30} is either (1) computed from measured V_S profiles collected from the open literature where such information is available (44% of all sites), of which 59% were measured to a maximum profile depth of 30 m or deeper; or (2) assigned using various proxies (56% of all sites) developed for different geographic regions and using different secondary information, including surface geology, topographic slope, elevation, and geomorphic terrain classification. Details of these proxies can be found in Table 1 of [21]. Z_{xx} is assigned from measured V_S profiles if available, or from 3D crustal velocity models available in the Cascadia subduction region and Japan (see details in [21]).

Flatfile

The flatfile is the summary table used to develop the GMMs. It includes key metadata and ground-motion parameters extracted from the aforementioned databases. Ground-motion parameters include PGA, PGV, PSA and FAS at selected frequencies and AI and significant-shaking durations between selected percentages of AI. PSA based on different definitions (i.e. as-recorded and RotDnn) are provided as described in [22]. The current approach is similar to past NGA databases [2, 3, 4] that are available through the PEER website [23].

Path-dependent parameters that are unique to each record are also included in the flatfile. Such parameters are epicentral distance, hypocentral distance, Joyner-Boore distance, and closest distance to the rupture surface. Because subduction earthquakes can be deeper than crustal earthquakes, and the database includes many large-magnitude events, the difference between these distance metrics can be significant.

Summary

The PEER NGA-Sub database includes a ground-motion database that compiles engineering seismological resources for different geographic regions around the world. The database combines parameters from different databases: the ground-motion database, earthquake-source database and site database. Moderate-to-large magnitude earthquakes are included for which time series were recorded by strong-motion or broadband seismograph stations. Time series were obtained from various agencies and were uniformly processed through the standard PEER data processing methodology [2, 3]. A variety of metadata are available to users, including uniformly processed time series, PGA, PGV, PSA, FAS, site condition and distance metrics. The developed ground-motion data are useful for GMM development for subduction-zone earthquakes.

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