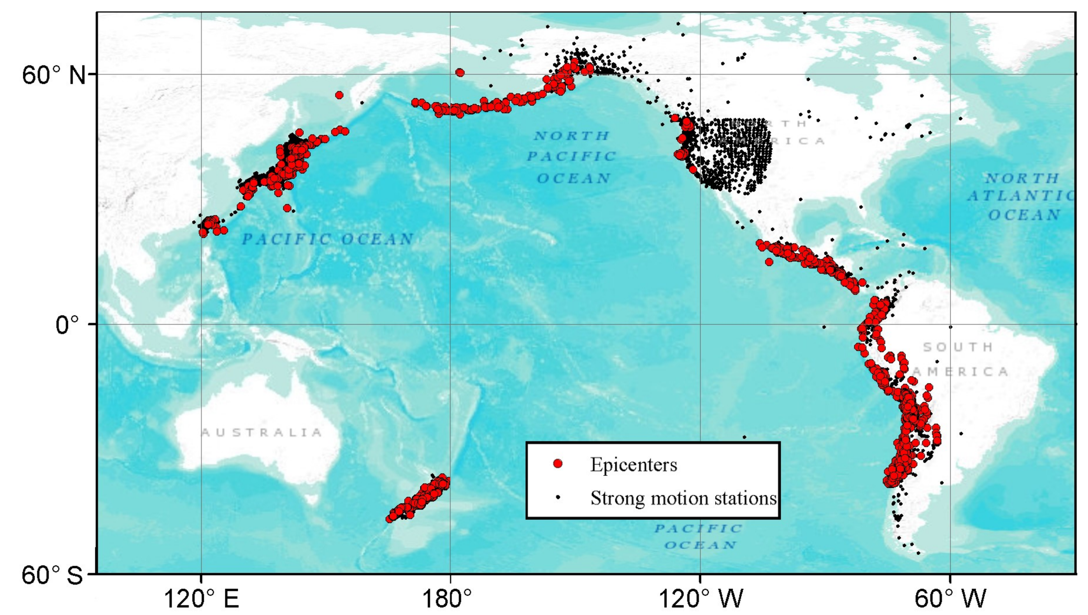
Earthquake Source Parameters for Chilean Events for use in the NGA-Subduction Project

Victor Contreras, Jonathan P. Stewart, *University of California, Los Angeles (UCLA);* Robert B. Darragh, *Pacific Engineering and Analysis*; Tadahiro Kishida, *Khalifa University of Science Technology and Research*; Robert R. Youngs, *Wood plc*

The NGA-Subduction project

The Next-Generation Attenuation (NGA) projects provide uniformly-processed ground motion data and supporting metadata related to source, path, and site parameters for earthquakes recorded in different tectonic settings and regions around the world. Currently, the Pacific Earthquake Engineering Research Center (PEER) is conducting the NGA-Subduction project (**NGA-Sub**), which is a major multi-year international project to develop database resources and ground motion models (GMMs) for subduction-zone earthquakes.



The project encompasses North America (including the Pacific Northwest, Alaska, and Mexico), Central America, South America, Japan, Taiwan, and New Zealand.

Figure 1. Location of the epicenters and the strong motion stations in the NGA-Sub database.

Earthquake catalog of the ground motions recorded in Chile

An earthquake-source database has been developed for events with ground motion recordings obtained in Chilean territory. Data from the South American subduction zone, and particularly from Chilean earthquakes, are critical for the success of this project, due to the availability of data from many large (**M** > 7.5) interface subduction events and the importance of significant regional path effects previously observed in Chile [1] but not evident elsewhere.

To date the event catalog for South America consists of 826 earthquakes that occurred from 1985 to 2016, of which 689 have been recorded at Chilean strong motion stations. Most of the recorded ground motions in Chile are concentrated in 2010, 2014, and 2015, associated with the occurrence of the 2010 **M**8.8 Maule, 2014 **M**8.2 Iquique, and 2015 **M**8.3 Illapel earthquakes and their aftershocks. The event database contains interface, intraslab, shallow crustal, and outer-rise earthquakes, ranging in magnitude from 2.5 to 8.8; however, it is dominated by interface (59%) and intraslab (32%) events.

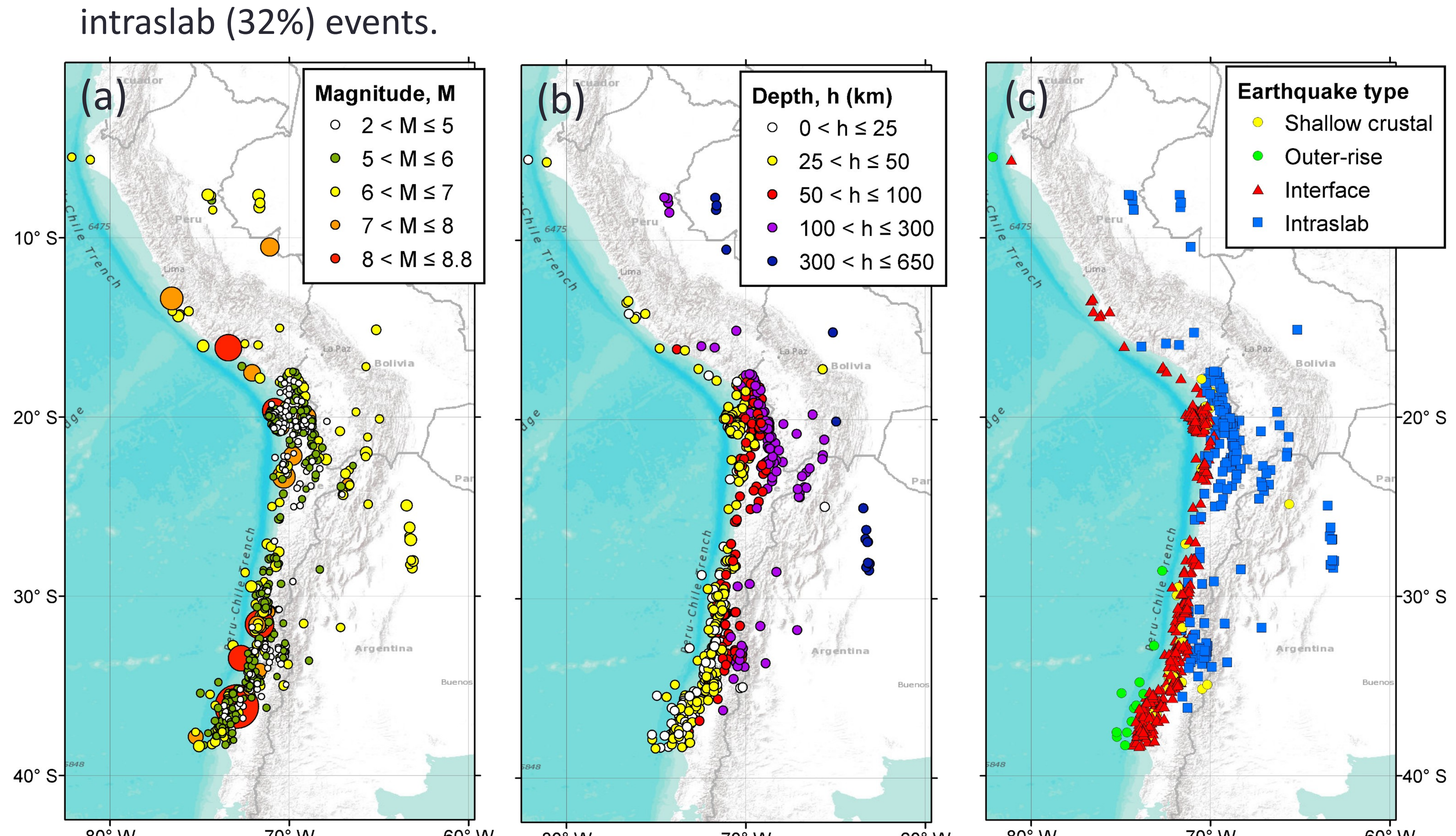


Figure 2. Geographical distribution of the earthquakes with ground motion recordings obtained in Chilean territory: (a) by magnitude; (b) by hypocentral depth; (c) by earthquake type.

Source database development

An essential component of the NGA-Sub database is a source database that contains information on seismic moment (M_0), moment magnitude (**M**), hypocenter location, nodal planes, and finite-fault geometric parameters. We have collected and evaluated more than 40 different finite-fault models (FFMs) available from previous studies. The preferred FFMs ideally have appeared in a peer-reviewed document (not preliminary or automatic solution) produced utilizing as much data as possible, including data from strong motion or broadband recordings.

As part of the NGA-Sub project, we have developed fault trimming methods to interpret published FFMs in a way that the most salient portion of the fault plane (significant slip) are used for source-to-site distance metrics. Details of the rationale behind these procedures will be presented in future publications, but the end result is that we trim the FFMs so as to encompass regions of the fault having slip that exceeds 15% of the maximum slip [2]. Such regions are defined by one or more rectangles. Table 1 summarizes the results for the eight large events with available FFMs indicating the selected finite-fault geometry parameters.

Table 1. Summary of the preferred finite-fault models.

Earthquake	M_0 (N·m)	**M**	FFM slip (cm)		Segment ID	strike (°)	dip (°)	rake (°)	Rupture dimensions*			
			Max	Trimmed					L (km)	W (km)	A (km²)	L/W
Maule 2010	1.78E+22	8.81	2129	319	1	15	18	109	480	160	76800	3.0
Arequipa 2001	4.20E+21	8.41	N/A	N/A	1	310	18	62	264	145	38280	1.8
Illapel 2015	3.70E+21	8.31	1070	161	1 2 3	3.7	10.5 17 23.5	109	240 140 130	50 38 55	24470	1.2
Iquique 2014	1.7E+21	8.15	670	101	1	357	18	106	157.5	105	16538	1.5
Antofagasta 1995	2.11E+21	8.02	387	58	1 2	4	18	97	180 150	91 52	24180	1.2
Valparaiso 1985	1.96E+21	7.98	329	49	1 2	5	15 30	90 110	255 180	75 60	29925	1.6
Tarapacá 2005	5.4E+20	7.78	>1000	200	1	187	23	-73	47.5	45	2138	1.1
Tocopilla 2007	6.24E+20	7.75	258	39	1	3	20	98	180	60	10800	3.0

** L = rupture length, W = rupture width, A = rupture area, L/W = aspect ratio.*

Figure 3(a) shows the location of the eight large earthquakes with available FFMs, whereas Figures 3(b) and 3(c) present the preferred FFM for the 2015 **M**8.3 Illapel earthquake, as an example.

For the large number of events that lack published FFMs, we applied uniform protocols for assigning M_0, **M**, hypocenter location, and moment tensor from results in the literature.

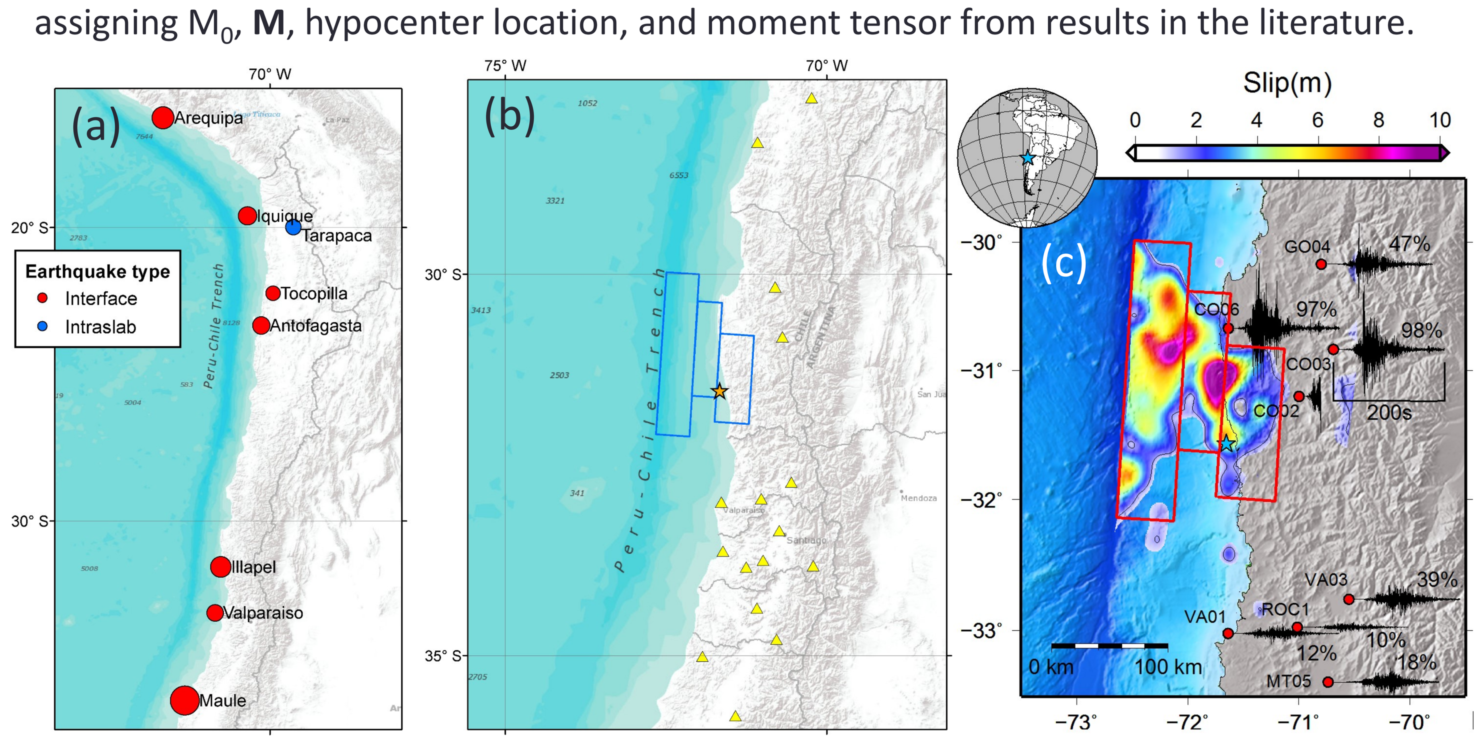


*Figure 3. (a) Epicenters of the earthquakes with available FFMs; (b) and (c) Preferred FFM for the 2015 **M**8.3 Illapel earthquake: maps showing epicenter (stars), surface projection of trimmed FFM, and strong motion stations (triangles/circles); (c) includes fault slip distribution and representative horizontal accelerograms from [3].*

Source-to-site distances are computed using a simulation-based representation of finite-fault parameters that is similar to that used previously in NGA-projects [4]. To support the use of these simulations for subduction zone earthquakes, we have developed relationships for **M**-rupture area, **M**-aspect ratio, and hypocenter locations in the down-dip and along-strike directions. Figure 4(a) shows the results of the regression fit performed using the NGA-Sub source data (from all regions, not only Chile) and the data points from [5], who also present magnitude-area scaling relations for interface subduction zone earthquakes. Our fit essentially matches that derived by [6]. Figure 4(b) presents the results for the aspect ratio of interface events.

Hypocenter locations of the analyzed Chile-Peru events in the down-dip direction are on average deeper than in other regions (e.g. Japan), whereas the average location along-strike direction is practically in the center of the fault plane (bi-lateral rupture). A detailed description of the source characterization methodology is presented in [2].

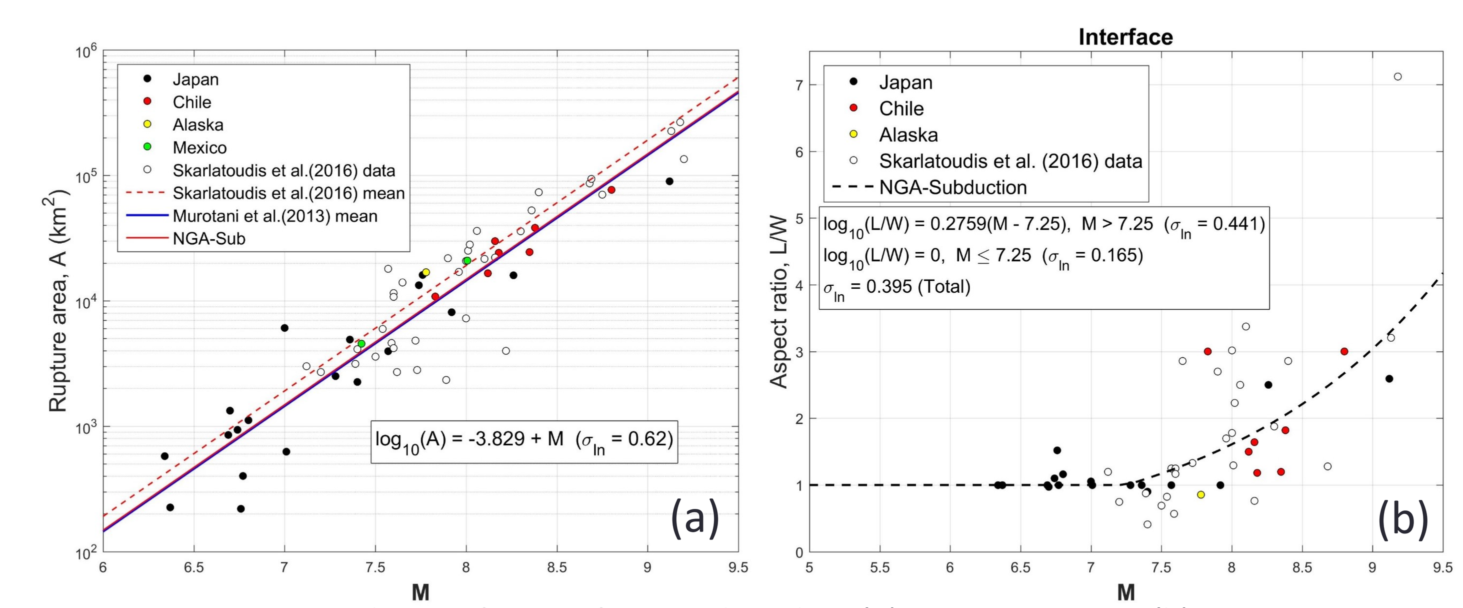


*Figure 4. Geometry relations for interface earthquakes: (a) **M**-rupture area; (b) **M**-aspect ratio.*

Summary

Eight finite-fault models have been selected and trimmed for large earthquakes in and near Chile. Seven of these earthquakes occurred on the plate interface and one from an intraslab rupture (Tarapacá, 2005). Metadata from these and other worldwide events are used to update the simulations for the other earthquakes without finite fault models in order to calculate various distance metrics.

The **M**8.8 Maule earthquake is the second largest earthquake in the NGA-Sub database and the time series and spectra from this and other earthquakes with recordings in Chilean territory are being used to delineate important regional differences in attenuation between the Chile-Peru and Japan/Taiwan regions.

Acknowledgements

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