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A new seismo-engineering ground-motion database for Israel

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ABSTRACT: The seismic activity in Israel and its surrounding neighbors originates mainly from the active Dead Sea transform. The historical and archeological records suggest a recurrence interval of approx. 10^2 and 10^3 years, for earthquakes of M6 and M7, respectively. Despite the existing hazard, local advancements on this topic have been slow and incremental, partly due to objective challenges, such as the limited number of recorded significant earthquakes and a limited azimuthal coverage. Consequently, limited effort to date has been made to compile all of the available data into one standardized, open resource for the scientific and engineering communities. This paper summarizes a joint effort, aimed at standardizing the catalog and creating the first of its kind, publicly-available ground motion database for Israel. The database is compiled of three main branches: the event database, the ground motion recording database and the site database.

1 INTRODUCTION

1.1 *Tectonic and seismological setting*

The seismic activity in Israel and its surrounding neighbors originates mainly from the active Dead Sea transform (DST), an approximately 1000 km long fault-system with left-lateral slip extending from the southern Red Sea to the collision zone in southern Turkey, separating the Arabian plate to the east from the African plate to the west. The historical and archeological records suggest a recurrence interval of approx. 10^2 and 10^3 years, for earthquakes of M6 and M7, respectively (Hamiel et al. 2009). The slip rate along the different segments of the DST vary between 4.5-5.4 mm/yr in southern Israel, decreasing to rates of 3.1-4.5 mm/yr in northern Israel, as inferred by recent geodetic studies (e.g. Sadeh et al. 2012, Hamiel et al. 2018).

1.2 *Seismic networks in Israel and the surrounding region*

The Israeli Seismic Network (ISN) was established in 1983 by the Geophysical Institute of Israel (GII), in order to monitor the local seismic activity. The ISN gradually grew to a total of twentythree seismometer stations, and about sixty strong motion accelerometer stations nowadays. A new network, including approx. 120 stations is currently being installed (expected completion date July 2019). The new network, once operational, will serve as part of a national earthquake early warning system called TRUA, according to a governmental decision, following recommendations of an international committee (Allen et al. 2012). The distribution of the current ISN stations is presented in Figure 1. The distribution of the stations is mostly limited to the western side of the DST, because of geographical and political constraints, which results in a limited azimuthal coverage of the recorded events.

In its approximately 35 years of operation, the ISN recorded over 16,000 events with duration magnitudes M_d (Shapira 1988) up to 5.4 within the boundaries of the state of Israel and one M_w 7.2 in 1995, in the Gulf of Aqaba, 60km south of the southern border of Israel. The

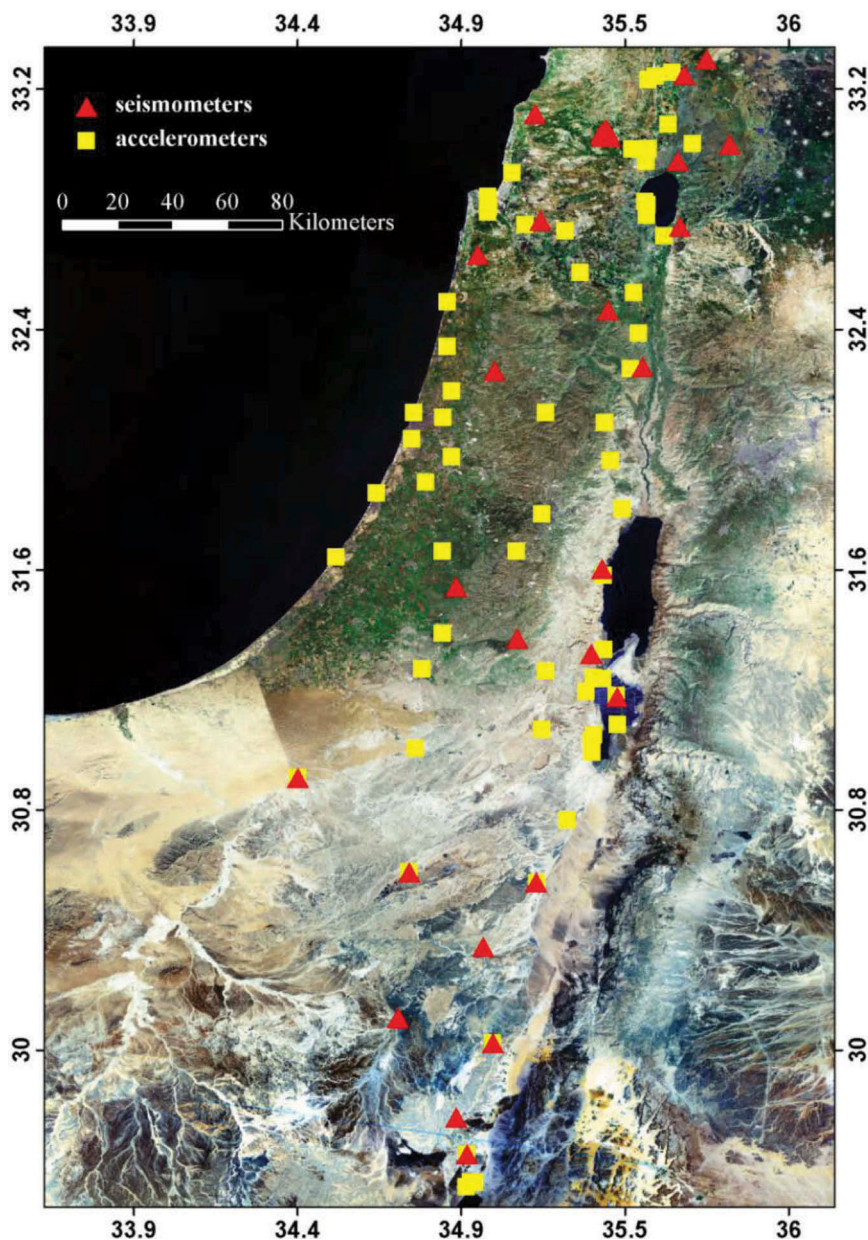


Figure 1. Israel Seismic Network station distribution, showing currently operational stations.

catalog completeness is considered as $M_d \geq 2$ as of 1986 (Shapira & Hofstetter 2002). Despite the renewal of the network and decommissioning of some of the old stations – it is imperative to create a uniform ground-motion database of the existing data, to be used in a range of engineering and seismological applications and needs.

1.3 Research objectives

The objective of the current research is to compile and distribute an Israeli ground-motion database, composed of data recorded by the ISN, intended for engineering applications,

which will be available to the public and the relevant academic and industrial communities. This ground-motion database will be compiled of three different databases: event database, record database and site database. These databases will be available online via FDSN protocol (FDSN) and WebDC interface (Bianchi et al. 2015).

2 DATABASES

2.1 Event database

Our event database is intended for seismological engineering applications, and therefore differs from the complete seismic catalog. The constraints that were used to select the events are based on the seismic network evolution during the years. Ongoing improvements in data quality and events detectability (e.g. more stations, higher sampling rates, more sensitive instrumentations etc.) have led us to select events with $M_d > 5.0$ between 1983 and 2007, and $M_d > 3.0$ since 2008.

Our catalog, which is a sub-set of the formal catalog published by the GII, is composed of 405 events, as presented in Figure 2.

The data provided by the GII is the timing, location, magnitude (M_d , in most cases), and depth of each event. For the 144 events which were also included in the re-located catalog of Wetzler & Kurzon (2016), we used the Wetzler & Kurzon (2016) location, magnitude and depth, because we believe those are more recent and better constrained.

The seismic moment was calculated using the relation of Hofstetter & Ataev (2011):

$$\log M_0 = 12.27 - 0.2M_d + 0.19M_d^2 \quad (1)$$

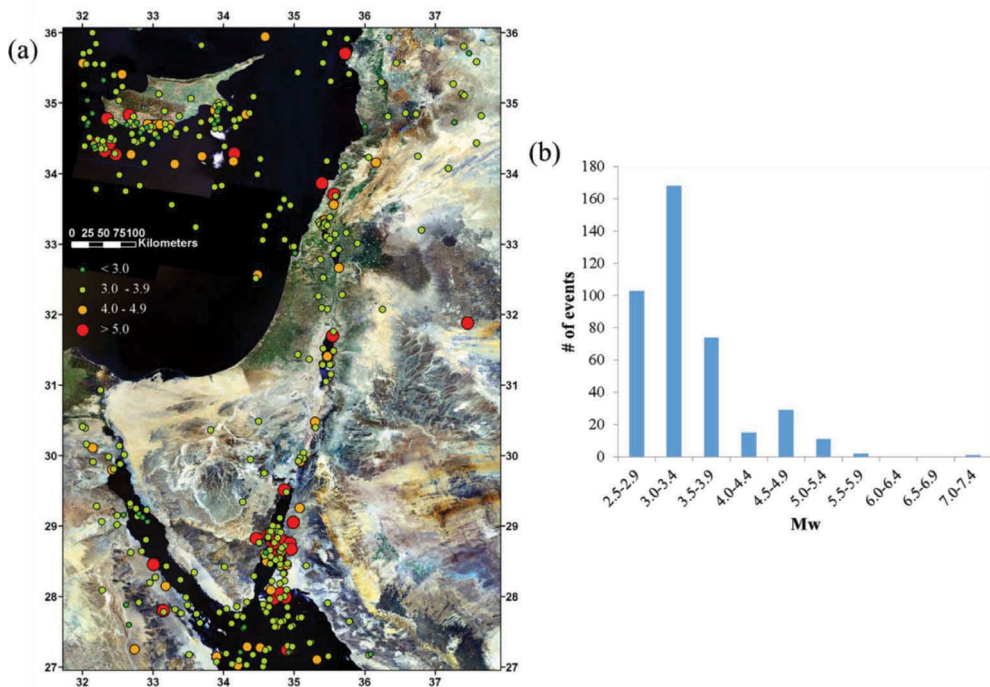


Figure 2. (a) Event catalog from GII. Events are classified by their magnitudes. (b) Magnitude frequency of the events in the catalog.

where M_0 is in [N-m] and then moment magnitude was calculated using the Hanks & Kanamori (1979) relation:

$$M_w = \frac{2}{3}(\log M_0 - 9.1) \tag{2}$$

Data regarding the focal mechanism and the slip model was collected from available resources and published research.

2.2 Ground motion database

The ground motion database is composed of 3169 records having two horizontal components, and 2968 records having all three components. Figure 3 presents the magnitude – distance distribution of the records having two horizontal components, as well as the frequency of different distance ranges in our catalog.

The raw time-history data is processed in order to remove noise and maintain consistency between different records. We generally follow the same protocol as suggested by the Pacific Earthquake Engineering Research institute (PEER) (Boore et al. 2012) and the Reference database for seismic ground-motion in Europe (RESORCE) (Akkar et al. 2014), presented in the flowchart in Figure 4, and briefly summarized below.

First the instrument response is removed from the data. Then, the time-series mean is removed, the record is tapered on both ends, and padded with zeros. A 4-pole band-pass acausal Butterworth filter is applied to the Fourier-spectra of the acceleration. The low-pass and high-pass corner frequencies are manually selected for each record, in an iterative process, until all noise is removed while maintaining maximum reliable data. A baseline correction is then applied, following Boore et al. (2012), as follows: The acceleration record is double-integrated to obtain displacement time-history, which is then fitted by a 6th order polynomial. Then, the fit is differentiated twice and is removed from the acceleration data – a step which removed much of the long-period rotations and deformations. Finally, the full Fourier Amplitude Spectra (FAS) of the processed acceleration record is obtained at discrete frequencies, as well as peak values, such as PGA and PGV. Figure 5 presents an example of one record before and after its processing.

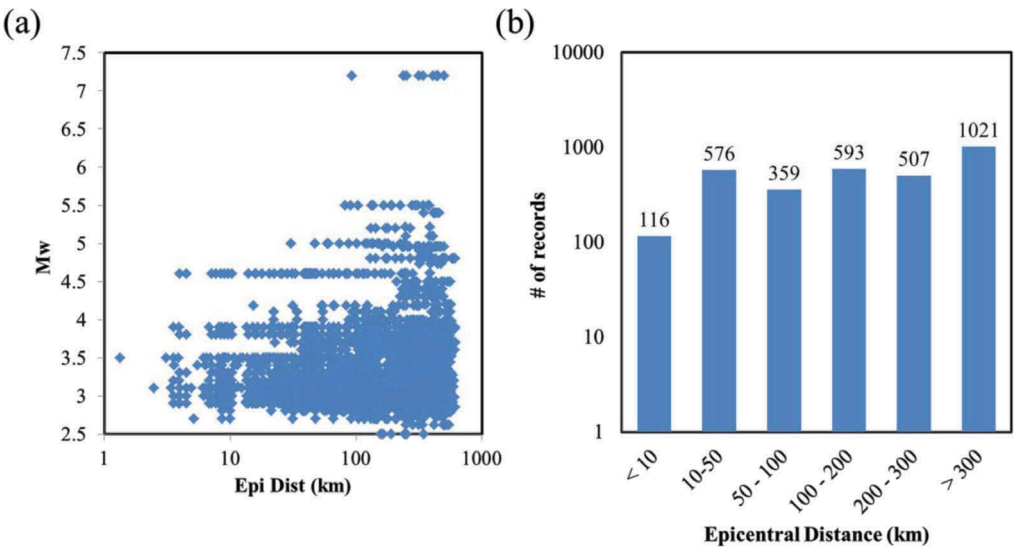


Figure 3. (a) Magnitude – distance distribution of the records in our database. (b) Distance frequency of records in our database.

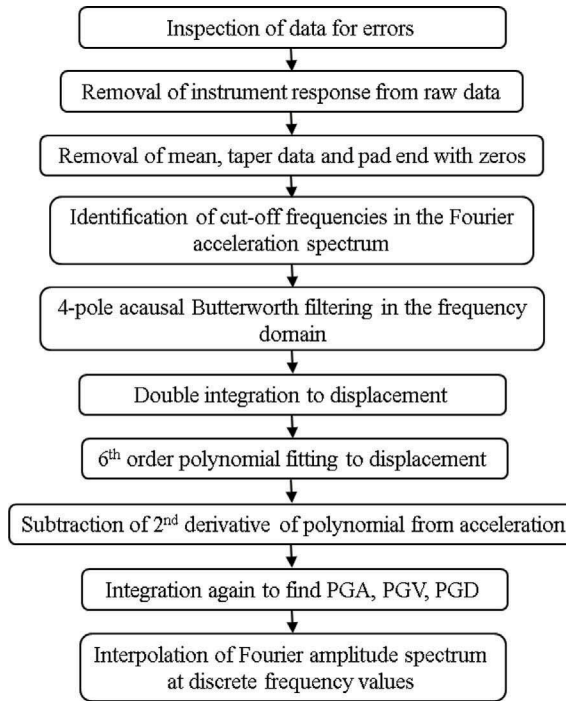


Figure 4. Flowchart describing the processing and filtering of the records.

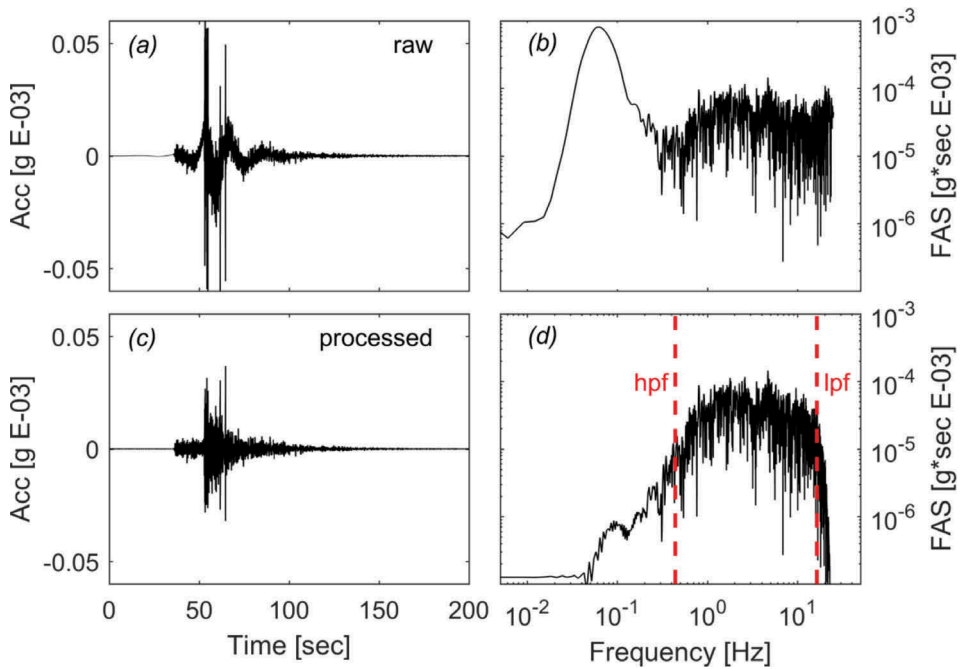


Figure 5. Example for the processing of a record of the Mw 5.2 11.2.2004 event, from the KZIT station: (a) and (b) the raw data waveform and FAS, respectively; (c) and (d) the processed data waveform and FAS, respectively. The highpass(hpf) and lowpass(lpf) filters are marked by the dashed red lines in subplot (d).

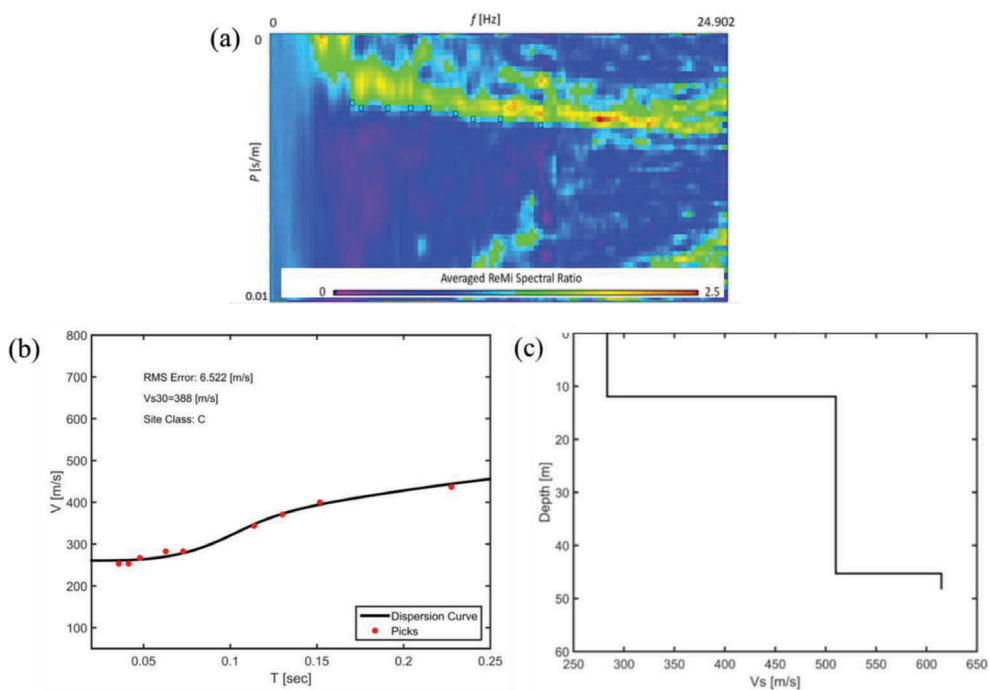


Figure 6. Processing and modeling of ALM station. (a) dispersion image and picking, (b) fitting a theoretical dispersion curve to the selected picks and (c) the final Vs model of the station.

2.3 Station database

This study presents a first effort to compile all the available data regarding ISN station characteristics, as well as collection of new field measurements collected systematically for the first time in the history of ISN.

Surface - wave dispersion measurements were taken at the ISN station locations, using the Refraction Microtremor technique (ReMi, Louie 2001). Such measurements allow us to obtain both the full shear-wave velocity (V_s) profile down to the available depth, as well as other proxies used for site response evaluation, such as the time-averaged shear wave velocity of the upper 30 meters, a parameter known as V_{s30} . Figure 6 presents an example for one data processing and final velocity profile obtained for one station in this study. In Figure 7 we present the V_{s30} values of the measured stations in our database.

For each station, data of the surface lithology is collected using 1:50,000 scale geological maps by the Geological Survey of Israel (GSI, www.gsi.gov.il). Furthermore, the depth to the top of the Judea Group – a Late Cretaceous group which consists of hard carbonate rocks, and is the main reflector in many regions of Israel, is collected using a structural map (Fleischer & Gafsoy 2003).

At this point, we have a complete database for 23 out of 25 seismometer stations, and 29 out of 60 strong motion stations. This database is constantly growing as we continue to conduct field measurements at station locations. Future measurements will include multiple techniques, including Multichannel Analysis of Surface Waves (MASW) and the modeled velocity profiles will be a result of a joint inversion of the different techniques. Using multiple approaches, even without performing a joint inversion for the profile, helps define the epistemic uncertainty in the velocity profile estimation, as different methods give different results, as recently shown by Kamai et al. (2018).

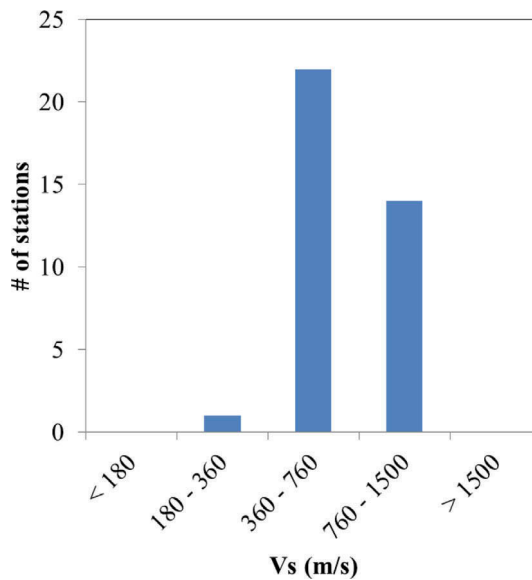


Figure 7. Frequency of V_{s30} values for the measured ISN station profiles in our database. V_{s30} bins are according to the NEHRP classification (Martin & Dobry 1994).

2.4 Flatfile

The flatfile is a product combining the three former databases. In the flatfile each row stands for a ground-motion record, providing all possible information regarding the earthquake source, the different distance measures between the earthquake epicenter/hypocenter and the station, the station characteristics, and ground motion intensity values, namely PGA, PGV, and FAS values at discrete frequencies. The flatfile is built in a similar way to the NGA project flatfile (Ancheta et al. 2013).

3 CONCLUSIONS

This paper presents an elaborate effort to compile all the available seismic data in Israel, in a way that will be clear, consistent, and most importantly available to the scientific and industrial communities, as well as to the public. As is evident from the data presented, there is a deficit in the high magnitude range, which will have to be addressed by each user of this database, according to their application and judgement.

Such a database, with all its components, is necessary for local seismo-engineering research, and can be used for other research fields as well, such as earthquake seismology.

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