Characteristics of high frequency ground motions in the Maule region (Chile), obtained from aftershocks of the 2010 Mw 8.8 earthquakes

GRUPPO NAZIONALE DI GEOFISICA DELLA TERRA SOLIDA

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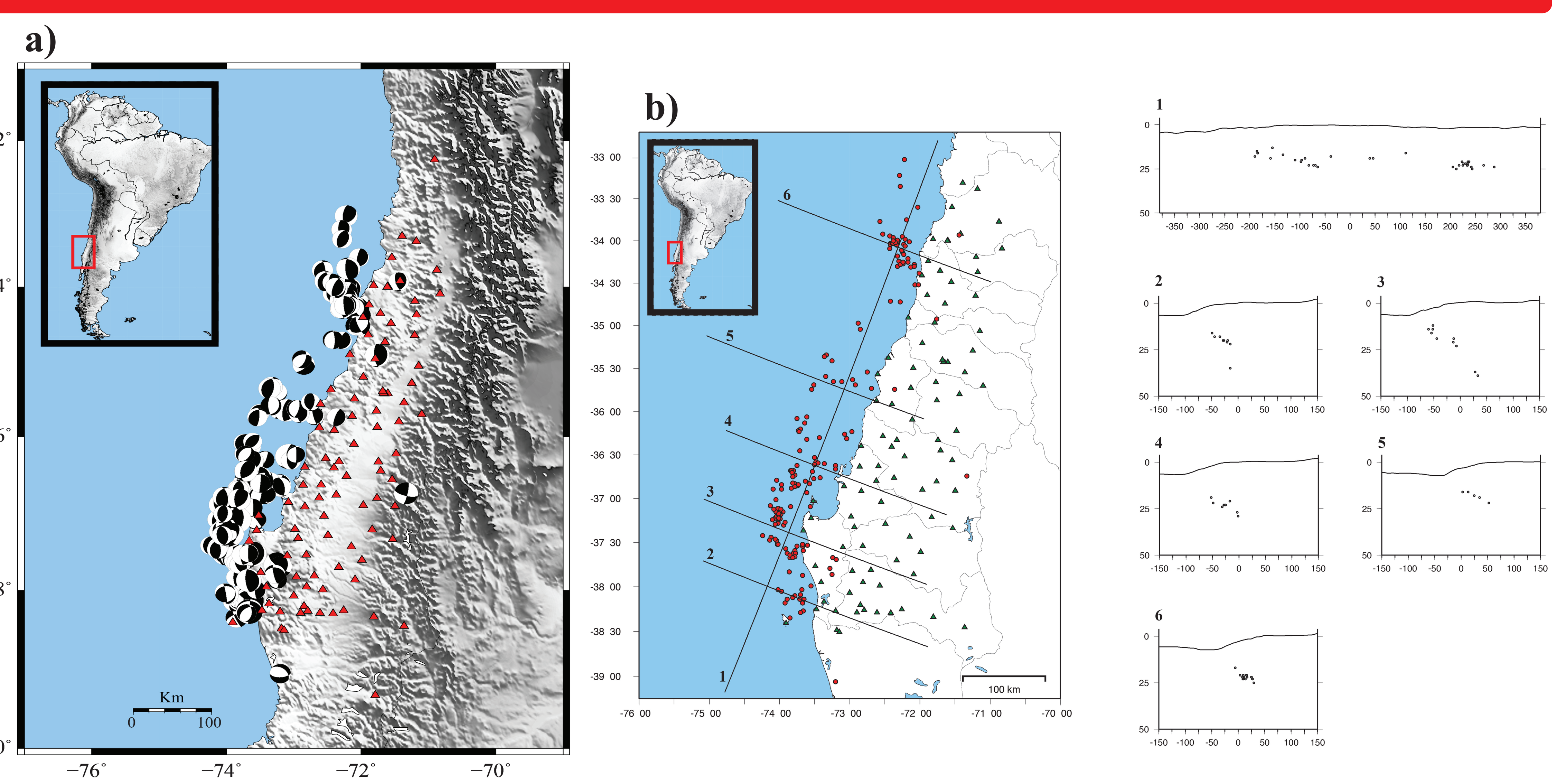
ABSTRACT

The Mw 8.8 Maule earthquake occurred off the coast of central Chile on 2010 February 27, and was followed by thousands of aftershocks. In this study, we modeled 172 aftershocks recorded by more than 100 temporary broadband stations deployed between March 2010 and January 2011. Each of these earthquakes is characterized by a well-determined hypocentral location and well-constrained focal mechanism and moment magnitudes in the range M 3.7 to 6.2. Most of these earthquakes are characterized by shallow, eastward-dipping, thrust-type focal mechanisms consistent with faulting at or near the plate interface, where the Nazca plate is subducting beneath the South America plate at approximately 74 mm/yr.

This study provides a unique opportunity to quantify high-frequency earthquake ground motion in a subduction zone due to the quality and quantity of observations in the frequency and distance range of 0.2-30 Hz and 40-500 km, respectively. The analysis was done using a two-step modeling procedure. A regression is performed to characterize source duration and excitation, source-receiver distance dependence, and station site effects. A point source forward model is then constructed in terms of geometrical spreading, duration, site effects and source scaling to match the regression results. This procedure provides the necessary point source parameters for stochastic finite-fault modeling of peak ground motions for future earthquakes in this subduction zone.

DATA SET

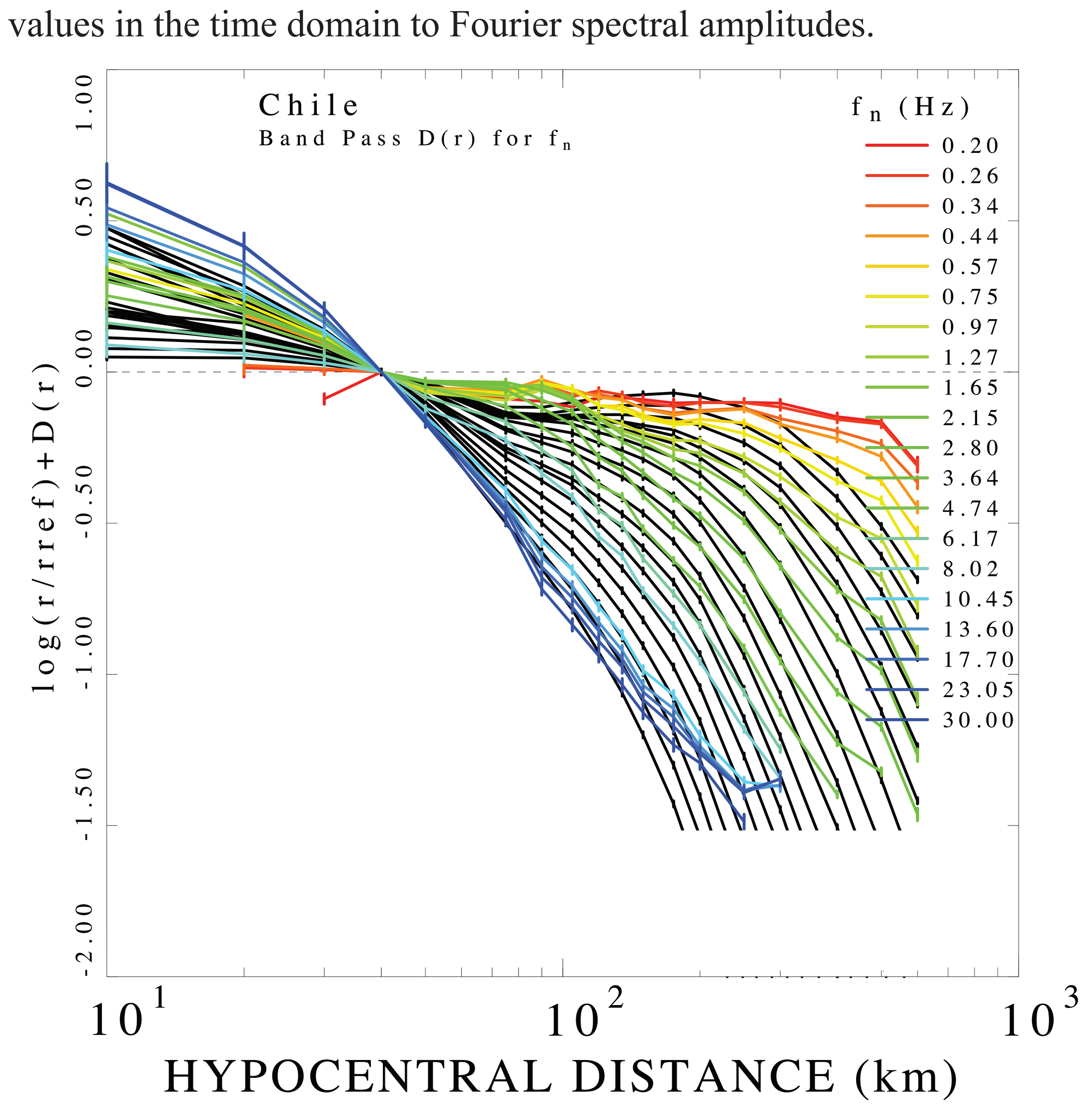


(a) Map of the Maule region (Chile). Beach balls indicate the moment tensor solutions of all 172 aftershock in the range Mw 3.7 to 6.2. Red triangles indicate the positions of the temporary broadband seismic stations used in this study. Each of these earthquakes use the relocations performed for National Earthquake Information Center (NEIC). The RMTs were determined using the WUS velocity model (Herrmann et al., 2011).

(b) Cross- sections (1-6) of subduction zone showing the area constrained in this work. Earthquake locations (red cricles) and stations (green triangles) are shown.

GROUND MOTION ANALYSIS

We calculated the time domain peak spectra, including their standard errors, from the regression of the following non-parametric equation: $A_n (f_i, r_{jk}) = SRC_j (f_i, r_o) + SITE_k (f_i) + D (r_{jk}, r_o, f_i)$ where: $A_n (f_i) = \log_{10} a_n (f_i)$ is the logarithm of the peak amplitude observed on a narrow bandpass-filtered version of the n-th time history, $SRC_j (f_i, r_o)$, recorded at a hypocentral distance r_{jk} by the k-th station, $SITE_k (f_i)$. The propagation term is indicated as $D (r_{jk}, r_o, f_i)$, and represents a contribution of the regional crustal structure that may be considered common to all recording sites. f_i is the central frequency of the bandpass filter. Finally, r_0 is an arbitrary hypocentral distance at which all source terms are referred (40 Km); this is achieved by forcing the constraint $D(r_{jk} = r_0, r_0, f_i) = 0$ to the i-th regression (e.g. see Malagnini er al., 2000). Given a stationary, random time history of length T', Random Vibration Theory (RVT, see Cartwright and Longuet-Higgins, 1956) may be used to estimate its peak value: $Peak(a(t)) \approx \eta a_{RMS}$, where the a_{RMS} is its RMS-average calculated over T' and $\eta = \eta(m_0, m_2, m_4)$ is a function of the specified spectral moments of the filtered time history. The Parseval and the convolution theorems, togheter with the Random Vibration Theory, can be used to completely switch from peak values in the time domain to Fourier spectral amplitudes.



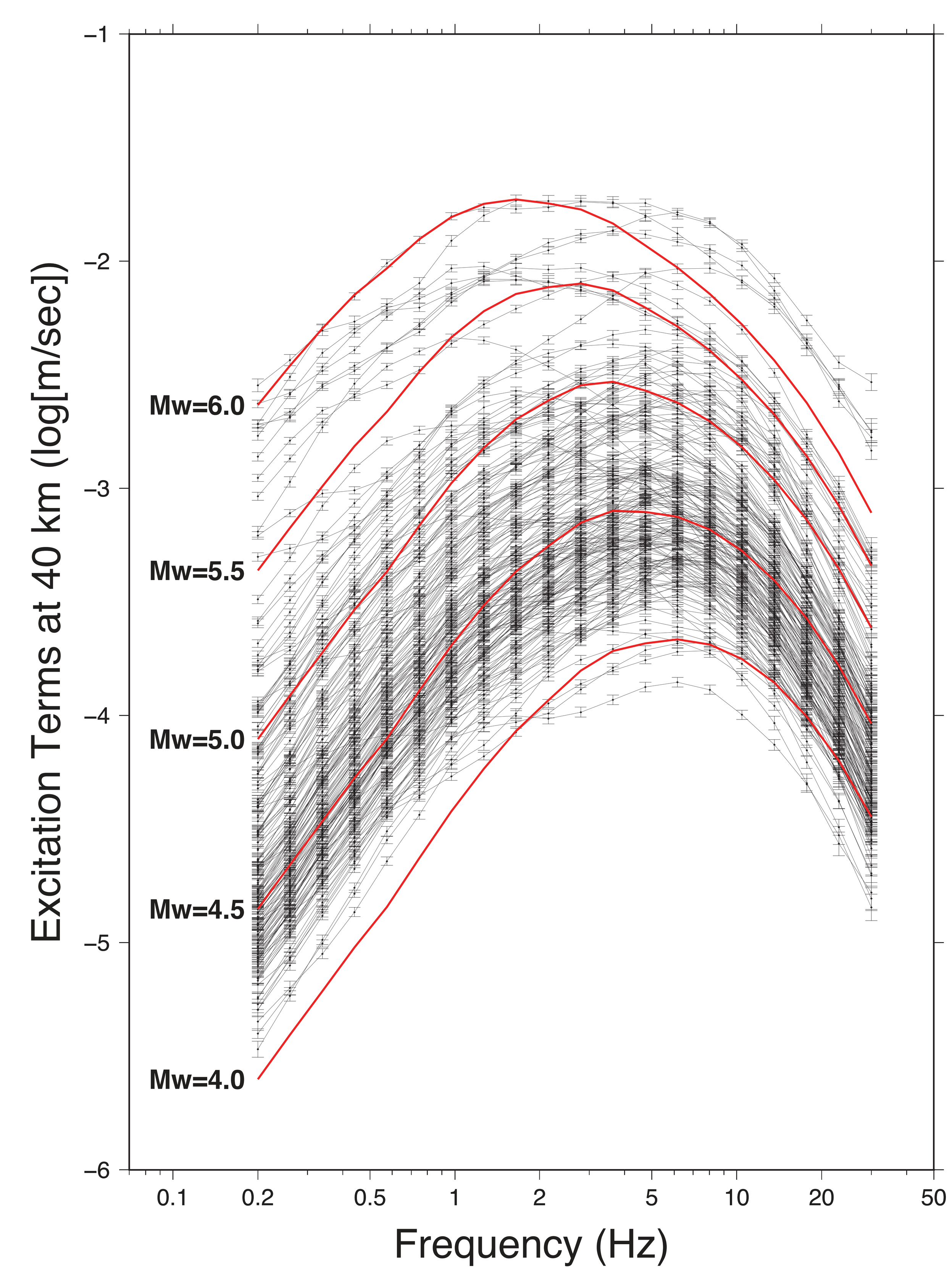
In this model of crustal attenuation we use to predict shapes and levels of the seismic spectra: ***g(r)*** = body-wave geometrical spreading; ***Q(f)***= crustal attenuation parameter; **Δσ** = stress drop; ***k***= residual sistematic attenuation parameter.

$k = 0.022$ $Q(f) = 100 f^{0.65}$

Km	g(r)	Km	g(r)	*Mw*	Δσ
1.0	-1.0	1.0	-1.0	*4.0*	*30*
50	-0.0	80	-0.0	*4.5*	*50*
200	-0.4	180	-0.2	*5.0*	*90*
		300	-0.5	*5.5*	*100*
				6.0	*100*

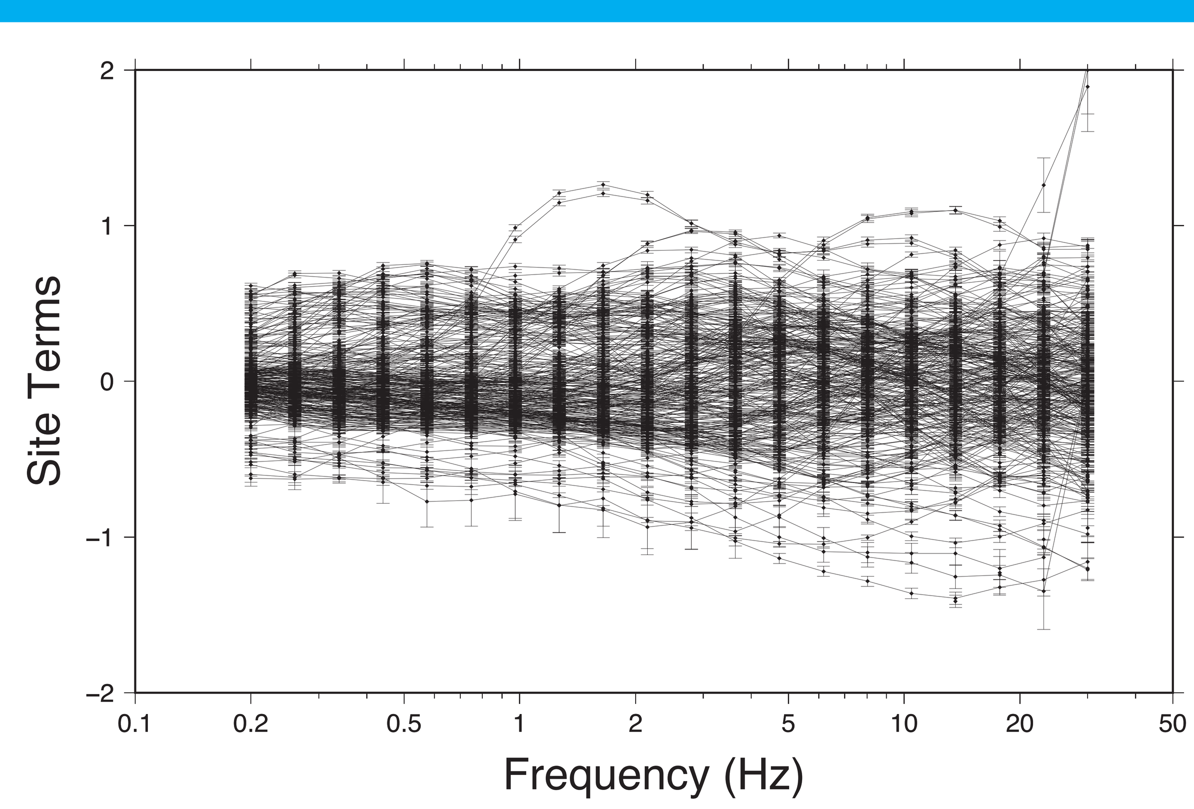
The regional attenuation functional D (r, r_{ref}, f) obtained for the Maule region from the regression on the peak amplitudes of the band-pass-filtered ground velocities at the sampling frequencies (color curves). The attenuation function is normalized to zero at the reference hypocentral distance of 40 km. The black curves in the background are from a attenuation model.

EXCITATION TERMS



Filtered ground velocity excitation terms relative to the aftershocks recorded during the Maule seismic sequence in 2010 (black lines). Red thick lines indicate the theoretical prediction at the indicated levels of moment magnitude.

SITE TERMS



This plot shows the site terms resulting from the regression on the entire data set of Chile.

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CONCLUSIONS

- For the first time a subduction earthquakes data set was used in our ground motion analysis;
- We completely calibrated the excitation and attenuation of the ground motion in Central Chile;
- It is evident that a constant stress drop cannot be use to fit the excitation term at all magnitudes;
- The parameters found in this study will be use to obtain accurate predictions of ground motion in this specific subduction zone.