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Scaling of source spectral parameters of moderate Kamchatka earthquakes: the prominent mismatch between trends for spectral and apparent stress drop

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Properties of source spectra of moderate (M_w = 3.5-6.5) Kamchatka subduction zone earthquakes were studied using S waves of more than 350 events, recorded by station PET and other five hard-rock stations at hypocentral distances is 50–250 km. The source spectra were approximated by a three-cornered shape (Gusev, 1983, 2012). In this way, many estimates of the first, f_{c1}, second, f_{c2} and third, f_{c3}, corner frequencies were obtained; here f_{c3} denotes the "source-controlled f_{max}". Only in about 1/3 cases, the low-frequency corners at f_{c1} and f_{c2} were sufficiently close to make a single $f_c = f_{c1} = f_{c2}$. Also, only in about 10% of cases, no indication of high-frequency f_{c3} cornerwas found up to 22-25 Hz. Thus, the majority of spectra shows three separate spectral corners and markedly deviates from the standard ω^{-2} spectral model. We determined scaling exponents $\beta_k = \mathrm{dlg}f_{ck}/\mathrm{dlg}M_0$ (k = 1, 2, 3). For β_1, common and orthogonal regression of f_{c1} data produce the interval estimate [0.28 0.34] that covers the value β = 1/3 expected for the case of source similarity; therefore our data on f_{c1} agree with this hypothesis. Correspondingly, no clear indication to (spectral) stress drop $\Delta\sigma$ dependence on M_0 is found. There exist however pronounced deviations from similarity for f_{c2} ($\beta_2 = 0.23\pm0.01$), and even more so for f_{c3} ($\beta_3 = 0.13\pm0.01$). Another data set of 460 spectra recorded by a single station PET was used to determine scaling of entire acceleration spectral shape, combining f_{ck} vs. M_0 trends (quite similar to the previously described ones) with trends of spectral level. From these trends, the new more accurate scaling law of source spectra is determined for the moderate-magnitude range, as a first step to complete specification of scaling law of source spectra of the region for calculations of scenario strong motions. The obtained spectral family shows, in the M_w range 3.5-5.5, the scaling of log acceleration spectral level as $M_0^{0.52}$, against $M_0^{1/3}$expected in the case of similarity. As a result of this fast increase (combined with other factors) apparent stress σ_a scales as $M_0^{0.36}$, in dramatic contradiction with the lack of any pronounced dependence of the same kind for $\Delta\sigma$. Thus, an important difference is revealed in the behavior of these two source parameters: one trend mostly agrees with the similarity concept, whereas another strongly contradicts it. This difference however seems to disappear at $M_w \geq$ 5.5-6; in this range, judging by scarce data, both $\Delta\sigma$ and σ_a seem to stabilize. It should be also noted that one might alternatively determine spectral stress drop $\Delta\sigma$ in a traditional manner, on the basis of the f_c definition after Savage (1972), through crossing of HF and LF asymptotes (or equivalently by fitting the prescribed ω^{-2} spectral shape to observed spectra). Such an approach would result in $f_c \approx (f_{c1} \times f_{c2})^{0.5}$ and $\Delta\sigma \propto M_0^{0.15-0.25}$, meaning much less pronounced difference between behaviors of g$\Delta\sigma$ and σ_a. The study was supported by the grant from the Russian Science Foundation (project 14-17-00621), and was carried out at the Kamchatka Branch of the Geophysical Survey of Russian Ac. Sci.