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Two empirical double-corner frequency source spectra and their source physics implications

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The best-known part of Brune's (1970) spectral model is the single corner f^{-2} source spectrum. However, Brune noted that a more realistic heterogeneous rupture would have a source displacement spectrum with a low-frequency f^{-0} segment proportional to seismic moment M_0 , a segment with f^{-2} high-frequency decay, and an intermediate f^{-1} branch that connects the two. This " f^{-0} - f^{-1} - f^{-2} " shape source spectrum features two corner frequencies f_{c1} and $f_{c2} > f_{c1}$. Brune (1970) associated the emergence of the f_{c2} with the partial stress drop over a fault considering a rupture with heterogeneous stress release. Here we introduce two double-corner source spectral models JA19 and JA19_2S for $3.3 \leq M \leq 7.3$, constrained by stochastic modeling the mean PGA and mean PGV of the NGA West-2 database. JA19 is self-similar. Its two corner frequencies f_{c1} and f_{c2} scale with moment magnitude (M) as (1) $\log(f_{c1}(M)) = 1.754 - 0.5M$ and (2) $\log(f_{c2}(M)) = 3.250 - 0.5M$. We find that relation (1) is consistent with the known self-similar scaling relations of the rupture duration (T_d) where $T_d = 1/(\pi f_{c1})$. Relation (2) may reflect scaling relation of the average rise time (T_R), where $T_R \sim 0.8/f_{c2}$. Stochastic simulations using JA19 cannot reproduce the sharp change in magnitude dependence of PGA and PGV at $M=5.3$, suggesting a breakdown of self-similarity. To model this change, JA19_2S is found by perturbing the f_{c1} scaling relationship in JA19. For JA19_2S: $\log(f_{c1}(M)) = 1.474 - 0.415M$ for $M \leq 5.3$ and $\log(f_{c1}(M)) = 2.375 - 0.585M$ for $M > 5.3$. In both models the relation $f_{c2}/f_{c1} \gg 1$ applies. Seismic radiated energy scales with $M_0^2 f_{c1}^2 f_{c2}$. The ratio f_{c2}/f_{c1} scales not only with the ratio of effective stress drop and static stress drop as Brune (1970) pointed out but also with the fault aspect ratio. The source spectral shape " f^{-0} - f^{-1} - f^{-2} ", originally proposed by Brune (1970), provides a bridge to reconcile the known scaling relationships in source duration, static stress drop, seismic radiated energy, fault aspect ratio, and ground motion parameters within acceptable uncertainties. It also explains why the stress parameter would generally be larger than static stress drop which is related to the lower corner frequency.