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Resolution of rupture directivity in weak events (Mw $\sim$ 5): a comparison of 1D and 2D source parameterizations

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Rupture directivity of small to moderate magnitude earthquakes may resolve the fault plane ambiguity and explain the disproportionate damage caused by some events. However, it is challenging to robustly resolve characteristic parameters such as direction, length, asymmetry and speed of rupture of weak events with short source durations. Here we infer directivity from apparent source time functions (ASTF) at regional distance and quantify the associated uncertainties. First, we use ASTF durations to model a propagating 1D line source with general asymmetry. Second, we use the full ASTF signals to invert for the 2D distribution of fault slip. Slip inversion is performed through a Popperian scheme, where random trial models are either falsified on account of large misfit, or else become member of the solution set of the inverse problem. We assess the resolution of rupture directivity representing centroid shifts from the solution set in a rose diagram. Using as example an event with well-studied rupture directivity, the 2011 Mw 5.2 Lorca (Spain) earthquake, 1D and 2D parameterizations yield similar estimates for direction (N213°E and N220°E respectively) and asymmetry (67:33, 65:35) of rupture propagation, as well as rupture length (2.1 km, 2.7 km) and speed (3.5 km/s, 3.25 km/s). The asymmetry of rupture is moderate, and the high rupture velocity $\geq$ 90% vS may be held primarily responsible for the strong directivity effect of this earthquake. Formal uncertainties of rupture extent and speed are large in the 1D model, while the more general 2D model produces larger uncertainties in rupture directivity and asymmetry. We show that inversion of apparent source durations is intrinsically unable to resolve highly asymmetric bilateral ruptures, while inversion of full ASTFs misses part of the signal's complexity, suggesting the presence of deconvolution artifacts. We extend the analysis to the Mw 4.6 foreshock of the Lorca earthquake, inferring similar directivity parameters and slip pattern as for the mainshock. The rupture towards SW and updip of both earthquakes suggests that this direction could be inherent to the fault segment.