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Kinematic and Dynamic source inversion in the low frequency range based on elliptical subfault approximations: application to the 2000 Tottori earthquake

S. Di Carli (1), R. Madariaga (1), C. Holden (2), and S. Peyrat (3)

(1) ENS, Geologie, paris, France (sdicarli@geologie.ens.fr), (2) GNS, GNS Science, Lower Hutt, New Zealand, (C.Holden@gns.cri.nz), (3) Institut de Physique du Globe de Paris, (peyrat@ipgp.jusieu.fr)

We develop a new kinematic and dynamic source inversion method based on the use of a small set of elliptical source patches. The near field strong motion data are integrated to displacement and band pass filtered between 0.1 and 0.5 Hz. At these low frequencies most earthquakes of magnitudes from 6.5 to 8 appear simple and therefore can be used to estimate average dynamic source parameters. Our approach is similar in spirit to Brume's circular crack model used in far field studies. We have applied this method to a particularly well instrumented earthquake, the 2000 Tottori earthquake. Kinematic models are a requisite in order to set a-priori bounds on the source parameters. Therefore we did a non-linear kinematic inversion with the neighborhood algorithm (NA) with a L2 norm that converges rapidly to a slip distribution with just two elliptical patches. Synthetics fit the strong motion data very well reducing the variance by 71%. Nonetheless the solution model is non-unique and needs to be validated through the dynamic inversion.

We propose a new dynamic inversion method based on the same geometrical idea.

Since dynamic inversion is intrinsically non-unique, so far we have only inverted barrier models. In a barrier model initial stress is uniform but rupture resistance is heterogeneous. Inversions may also be carried out independently within the asperity model, where initial stress is variable and rupture resistance uniform. For dynamic inversion, the direct problem has to be solved accurately on a coarse numerical grid, so that the models retrieved from the inversion must be checked for convergence in finer grids. We discuss briefly different approaches for the direct problem, but classical rectangular grids are inappropriate because of numerical scattering and dispersion produced by cell boundaries. We use again the neighborhood algorithm (NA) for the inversion with an L2 norm for the residuals. We do a limited exploration of the a posteriori error distribution. Our experience with dynamic and kinematic inversion indicates that only a small number of parameters (eigenvalues in linearized inversion) are resolvable from low passed filtered near field data. For the most complex earthquake studied so far, only 10 parameters could be resolved.

Within the barrier model, at least, we find that these parameters are mainly geometrical (position, sizes and orientations of the ellipses). Dynamic parameters (level of initial stress and rupture resistance) are strongly connected by kappa, the non-linear parameter that controls rupture propagation in dynamic sources. These models can be inverted in a parallel computer with 24 nodes in about 12 hours. Variance reduction for kinematic and dynamic models are very similar, close to 70% of the initial variance is explained by our models. By making different assumptions about the rupture process we illustrate the non-unicity of the dynamic solution. Once a low frequency inversion has been obtained, it is possible to explore higher frequencies using the low frequency model as a reference.