EGU2020-12695
https://doi.org/10.5194/egusphere-egu2020-12695
EGU General Assembly 2020

Simulation of Rotational ground motion in the near field region

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In recent times, seismic rotational motions have received significant attention of seismologists as well earthquake engineers. The measurement of rotational motions is useful not only for the complete characterization of the ground motion, but also for estimating the additional risk to civil engineering structures posed by these motions. With the development of state-of-the-art instruments such as the ring-laser and fiber-optic gyroscopes, and mechanical and magneto-hydrodynamic devices, it is now possible to measure these motions over a large frequency bandwidth with accuracy. Nevertheless, nearly all earthquake-prone regions of the world lack the instrumentation to record these motions and the existing database of recorded rotational motions thus remains limited. In such situations analytical methods can provide estimates of rotational ground motions. It is thus common to simulate these motions and most analytical methods simulate rotations as curl of the displacement field. Because this relation (refer to as 'curl-based') is based on the 'small deformations' assumption, the 'curl-based' rotations are in a sense an approximation of the exact rotations, the latter being computed by using the rotational matrix directly extracted from the deformation gradient using the polar decomposition theorem. Despite this, no study has so far discussed the situations in which the 'curl-based' relation no longer holds. This paper therefore attempts to shed light on this issue by conducting two numerical studies. In the first study, a simple case of a point kinematic dislocation shear source buried in a homogeneous, elastic half-space is considered to get a qualitative idea about the combinations of the source and medium parameters that can lead to appreciable errors in the 'curl-based' rotations. The second study considers the finite-fault source model of Chi-Chi earthquake to illustrate these errors in a realistic scenario. Both these studies indicate that the 'curl-based' rotations can be in appreciable error when 'exact' rotations are in excess of 20 degrees and that this can happen in the near-field regions of surface-rupturing faults.