Three-Dimensional Seismic-Wave Propagation Simulations in the Southern Korean Peninsula Using Pseudodynamic Rupture Models

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ABSTRACT

Accurate and practical ground-motion predictions for potential large earthquakes are crucial for seismic hazard analysis of areas with insufficient instrumental data. Studies on historical earthquake records of the Korean Peninsula suggest that damaging earthquakes are possible in the southeastern region. Yet classical ground-motion prediction methods are limited in considering the physical rupture process and its effects on ground motion in complex velocity structures. In this study, we performed ground-motion simulations based on rigorous physics through pseudodynamic source modeling and wave propagation simulations in a 3D seismic velocity model. Ensembles of earthquake scenarios were generated by emulating the one- and two-point statistics of earthquake source parameters derived from a series of dynamic rupture models. The synthetic seismograms and the distributions of simulated peak ground velocities (PGVs) were compared with the observations of the 2016 M_w 5.4 Gyeongju earthquake in the Korean Peninsula. The effects of surface-wave radiation, rupture directivity, and both local and regional amplifications from the 3D wave propagation were reproduced accurately in the spatial distribution of simulated PGVs, in agreement with the observations from dense seismic networks by mean log residuals of −0.28 and standard deviations of 0.78. Amplifications in ground motions were found in regions having low crustal velocities and in regions of constructive interference from the crustal shear-wave phases associated with postcritical reflections from the Moho discontinuity. We extended the established approach to earthquake scenarios of M_w 6.0, 6.5, and 7.0, at the same location, to provide the distribution of ground motions from potential large earthquakes in the area. Although we demonstrate the value of these simulations, improvements in the accuracy of the 3D seismic velocity model and the scaling relationship of the source models would be necessary for a more accurate estimation of near-source ground motions.

KEY POINTS

- We simulated seismic-wave propagation in the 3D Korean Peninsula model for pseudodynamic rupture scenarios.
- Surface-wave radiation, rupture directivity, and 3D amplification effects were accurately modeled.
- The physics-based simulations provide constraints on seismic hazard characterization in the Korean Peninsula.

Supplemental Material

INTRODUCTION

A critical dilemma in seismic hazard assessments for regions with low-to-moderate seismicity is that the instrumental records of large earthquakes are insufficient to provide ground-motion data for a wide range of earthquake magnitudes. The lack of instrumental data presents challenges in accurately estimating the extent of ground shaking from earthquakes in the region, especially when the magnitudes of historical earthquakes are substantially larger than those of the available data. Events such as the 1811 Mississippi valley earthquake of magnitude 7.6 and the 1886 Charleston earthquake of magnitude 6.9 indicate that large earthquakes can occur even in regions

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