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Simulations of Strong Ground Motion and 3D Amplification Effect in the Taipei Basin by Using a Composite Grid Finite-Difference Method

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Abstract We perform full elastic wave-field simulations within the Taipei basin by using a three-dimensional (3D) discontinuous finite-difference method. The 3D Taipei basin model is determined from a seismic reflection study. Two major subsurfaces, the Songshan formation (surface soil layer) and the basin basement, are constituted in the model. A parallel-based composite grid technique, a containing scalene grid and a discontinuous grid, is developed in this study to deal with the possible numerical problem of thin depth and low velocity of the Songshan formation. Taking advantage of the composite grid, the resolution of the subsurface structure can be reached to 20 m, and a higher frequency (up to 3 Hz) of the synthetic waveform can be achieved. In our strong ground motion simulations, we assume a constant velocity in each subsurface. Three different types of models are considered in the study: the Songshan formation with a basement structure model, a basin basement model, and a layered half-space model. Results indicate that only the model with both the Songshan formation and the basement structure can produce the apparent basin amplification effects. First, the surface wave generated after the primary *S* wave is trapped at the shallow part of the basin. Then, when the wave propagates through the deepest part of the basin, most of the energy is reflected from the boundary and focused back into the basin. In addition, part of the seismic wavefront turns and follows the shallow basin edge resulting in further amplification. Our study indicates that the complex Taipei basin geometry and fairly low velocity of the Songshan formation dominate the amplification and wave propagation behavior that result in extraordinary strong shaking patterns in the Taipei metropolitan region.

Introduction

The city of Taipei is built upon a sedimentary basin in northern Taiwan that is made up of Quaternary alluvium and lake deposits. Seismic disasters in the Taipei basin over the last 20 yr, particularly during the 1999 Chi-Chi earthquake (M_L 7.3) and the 31 March 2002 east coast earthquake (M_L 6.8) caused significant building damage and collapse events with considerable casualties (Wen *et al.*, 1995; Wen and Peng, 1998; Chen, 2003). Although these earthquakes are located more than 100 km from the basin, the shaking intensity within the basin is even larger than some areas near the epicenter. The unconsolidated sediments in the Taipei basin are made up of alluvial deposits from the TanShui River, and the youngest deposit, the Songshan formation, is formed by a layer of relatively thin depth (about 50 m) with a fairly low *S*-wave velocity. Previous studies concerning basins indicate that low velocity materials and basin geometry have a strong influence on the behavior of seismic-wave propagation (Yomogida and Etgen, 1993; Alex and Olsen, 1998; Davis *et al.*, 2000) and strengthen/lengthen shaking activity (Olsen *et al.*, 1995, 1996; Olsen, 2000; Graves 1998; Komatitsch *et al.*, 2004). Taipei basin's soft surface layers, in particular, make the heavily populated city particularly vulnerable to severe earthquake damage.

The Taipei basin amplification effect can be controlled further by several factors that vary with the varying basin structure. Numerical simulations have been successfully used to study the complex nature of strong-motion wave propagation in basins (Olsen *et al.*, 1995, 1996; Olsen, 2000; Graves, 1998). Because of a lack of empirical strong ground motion observations, theoretical simulations constitute our best hope of addressing this issue. From the results of combining seismic reflective profiles and borehole data (Wang *et al.*, 2004), we have established a high-resolution basin geometry model with a resolution as fine as 20 m to estimate the 3D seismic response of the Taipei basin. We put emphasis on the response to the surface soil and basin geometry by considering a simple point source. Results can be generalized to extended sources. To distinguish the case of the amplification effects, three models with different hypotheses are analyzed. Ground-motion behavior in the Taipei ba-