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Low-Frequency 3D Wave Propagation Modeling of the 12 May 2008 M_w 7.9 Wenchuan Earthquake

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Abstract The seismic potential of southern China is associated with the collision between the Indian and the Eurasian plates. This is manifested in the western Sichuan Plateau by several seismically active systems of faults, such as the Longmen Shan. The seismicity observed on the Longmen Shan fault includes recent events with magnitudes of up to 6.5, and the one of 12 May 2008 M_w 7.9 Wenchuan earthquake. Herewith, as part of an ongoing research program, a recently optimized three-dimensional (3D) seismic wave propagation parallel finite-difference code was used to obtain low-frequency (≤0.3 Hz) 3D synthetic seismograms for the Wenchuan earthquake. The code was run on KanBalam (Universidad Nacional Autónoma de México, Mexico) and HECToR (UK National Supercomputing Service) supercomputers. The modeling included the U.S. Geological Survey 40×315 km^2 kinematic description of the earthquake's rupture, embedded in a $2400 \times 1600 \times 300$ km^3 physical domain, spatially discretized at 1 km in the three directions and a temporal discretization of 0.03 s. The compression and shear wave velocities and densities of the geologic structure used were obtained from recently published geophysical studies performed in the Sichuan region. The synthetic seismograms favorably compare with the observed ones for several station sites of the Seismological and Accelerographic Networks of China, such as MZQ, GYA, and TIY, located at about 90, 500, and 1200 km, respectively, from the epicenter of the Wenchuan event. Moreover, the comparisons of synthetic displacements with differential radar interferometry (DinSAR) ground deformation imagery, as well as of maximum velocity synthetic patterns with Mercalli modified intensity isoseist of the 2008 Wenchuan earthquake, are acceptable. 3D visualizations of the propagation of the event were also obtained; they show the source rupture directivity effects of the M_w 7.9 Wenchuan event. Our results partially explain the extensive damage observed on the infrastructure and towns located in the neighborhood of the Wenchuan earthquake rupture zone.

Introduction

The seismicity of central–southern China is related to the collision between the Indian and the Eurasian plates. In the western Sichuan Plateau (eastern Tibetan Plateau), this collision generates several seismically active systems of faults, such as the Longmen Shan fault system (Densmore *et al.*, 2007; Robert *et al.*, 2009), where the hypocenter of the 12 May 2008 M_w 7.9 Wenchuan earthquake is located at a depth of 10–20 km (U.S. Geological Survey [USGS] data, see Data and Resources section). Among other manifestations of the collision, recent Global Positioning System measurements of crustal motion in the central eastern Tibetan Plateau and its adjacent foreland indicate a shortening of about 3 mm/year within the Longmen Shan region; this suggests an average recurrence interval of seismic activity from 2000 to 10,000 years (Burchfield *et al.*, 2008). This Longmen Shan region is located between the western Sichuan Plateau and the Sichuan basin (Fig. 1). The Sichuan basin is part of the Yangtze craton, and the collision between the latter and the Tibetan Plateau is supposed to have produced the thickening of the lower crust and the uplift of the western Sichuan Plateau (Wang *et al.*, 2007). Another manifestation of this collision is the seismicity in the region: it includes earthquakes with magnitudes ≤6.5 on and close to the Longmen Shan fault system and with magnitudes up to 8 in its vicinity, at least since 1879, until the 12 May 2008 M_w 7.9 (M_s 8) event, as shown in

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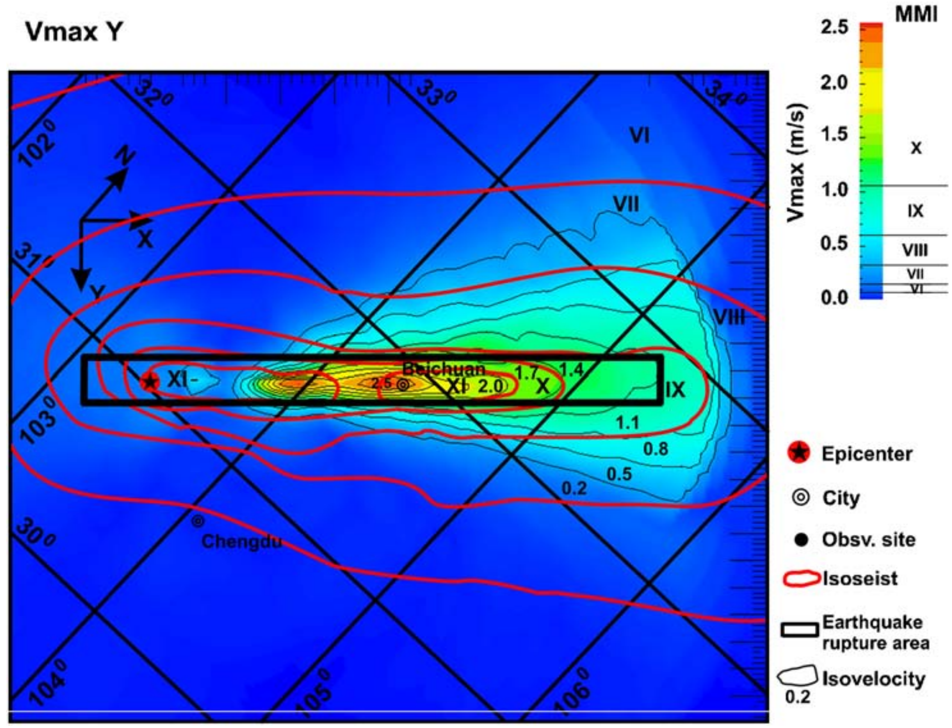

Figure 18. Comparison of the maximum synthetic velocities propagation pattern (isovelocities V_{max}) in the Y direction with the Mercalli modified intensity isoseist (fig. 3.1 in Yuan and Sun, 2008) of the 12 May 2008 Wenchuan M_w 7.9 earthquake. The color version of this figure is available only in the electronic edition.

seismograms for several station sites of the Seismological and Accelerographic Networks of China (MZQ, GYA, and TIY) located at about 90, 500, and 1200 km from the epicenter of the Wenchuan event, respectively, is acceptable. The comparisons of the maximum permanent synthetic displacements with DinSAR ground deformation imagery, as well as of maximum velocity synthetic patterns with Mercalli modified intensity isoseists of the 2008 Wenchuan earthquake are also acceptable. From the 3D visualizations of the propagation of the modeled earthquake obtained in this work, the largest amplitudes in the X (rupture direction), Y (perpendicular to X), and Z velocity wave fields occurred in the rupture direction of the Wenchuan earthquake. These results partially explain the extensive damage observed on the infrastructure and towns located on top and in the neighborhood of the Wenchuan earthquake rupture zone.

Data and Resources

The supercomputers KanBalam (Universidad Nacional Autónoma de México, Mexico) and HECToR (UK National Supercomputing Service) were used to run the code. The seismograms used in this study were provided by the Seismological Network of China and the accelerogram from station MZQ by the China Digital Strong Motion Network, and they cannot be released to the public. The kinematic slip distribution, the strike, dip, and rake of the 2008 Wenchuan earthquake were obtained from the U.S. Geological Survey Preliminary Result of the May 12, 2008, M_w 7.9 Eastern Sichuan, China, Earthquake, Finite Fault Model using http://earthquake.usgs.gov/earthquakes/eqinthenews/2008/us2008ryan/ (last accessed May 2008).

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References

Aagaard, B. T., T. M. Brocher, D. Dolenc, D. Dreger, R. W. Graves, S. Harmsen, S. Hartzell, S. Larsen, and M. L. Zoback (2008a). Ground-motion modeling of the 1906 San Francisco earthquake, Part I: Validation using the 1989 Loma Prieta earthquake, *Bull. Seismol. Soc. Am.* **98,** no. 2, 989–1011, doi 10.1785/0120060409.

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