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Comparison of fault models of the 2008 Wenchuan earthquake (Ms8.0) and spatial distributions of co-seismic deformations

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A B S T R A C T

A proper slip fault model and a reasonable dislocation theory are necessary to compute and investigate co-seismic deformations caused by the 2008 Wenchuan earthquake (Ms8.0). To find such a model, several comparisons are made of different dislocation theories, seismic fault models, and earth models. Results indicate that the fault model determined by combining GPS and seismic waveform data is the best. The spherical dislocation theory yields better results than that of a half-space theory, and the results obtained from a revised PREM earth model are better than those from PREM. According to results of earlier investigations, co-seismic deformations such as the displacement, geoid, gravity, and strain changes caused by the 2008 Wenchuan earthquake (Ms8.0) are computed, described, and discussed. Results show that the earthquake generated considerable co-seismic deformation in a large area around the epicenter. The modeled deformations are applicable as a reference for other researchers to study inter-structural inversion, crustal deformation, etc. The effects of the curvature and layer structure are great. Moreover, spherical dislocation theory is necessary for studying co-seismic deformations caused by a large event.

1. Introduction

The tragic 2008 Wenchuan earthquake (Ms8.0), which occurred on May 12, is the latest of a series of earthquakes in the earthquake-prone Tibetan region. The earthquake occurred in an area that is deforming because of the collision of two tectonic plates that has continued now for 50 Ma: the Indian plate and the Eurasian plate. This collision has created the high mountains and widespread seismicity observed throughout central Asia. The area between India and Asia covers a wide region that is undergoing large strain and deformation, thereby engendering the Wenchuan earthquake. Fig. 1 (left) portrays the location of the 2008 Wenchuan earthquake (31.0°N, 103.4°E). The blue star represents the location of the main quake. The earthquake occurred where the Indian plate, forced further eastward, overrides the Sichuan Basin at a rate of about 4 mm/year. This is the cause of the ongoing rise of the Longmen Shan mountain range, which marks Tibet's eastern border. The motion of the landmasses, as shown in the figure, is sensed at GPS stations of the region (Wang et al., 2001). Seismological measurements indicate that the 2008 Sichuan earthquake reached a magnitude of about Ms8.0, rupturing the Longmen Shan central fault. The rupture of the fault started in Wenchuan northwest of Chengdu and then traveled about 300 km northeastward along the front of the mountain range. The source depth is about 14 km below the surface. Aftershocks occur mainly along and near the fault line ruptured by the original May 12 quake, distributed in the middle-northern fault from Yingxiu to Qingchuan (Zhang et al., 2008a). Field geological investigations have detected two surface ruptures: 240 km along the Yingxiu–Beichuan fault, and 70 km along the Guanxian–Jiangyou fault, with maximum vertical and horizontal displacements of 6 m and 4.7 m, respectively (Xu et al., 2008; Zhang et al., 2008a).

To model the seismic fault model, several investigators have presented different slip distributions (fault models), using seismic waveform data, or seismic waveforms plus GPS-observed displacements, such as those by Ji and Hayes (2008), Zhang et al. (2008b), and Wang et al. (2008). The three slip models are fundamentally similar in terms of size and seismic moment, but with vastly different details. A comparison among the three models should be made to choose the best one for interpreting observed geodetic and geophysical data, and for studying the co-seismic deformations. For this purpose, as a judgment standard, we use the GPS determined co-seismic displacements observed before and after the quake. Fig. 1 (right) depicts the positions of GPS stations at which measurements were taken after the earthquake, including three classes: the red stars represent the continuous GPS stations; the blue stars denote the regional basic GPS stations; and yellow stars show C class GPS stations, which belong to national control network. In the following sections, we introduce more details about the slip models and GPS displacements.

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