The May 23 and 24, 1994 Taiwan earthquakes: comparison of source process between the two events

YU-MEI HE (何玉梅) TIAN-YU ZHENG (郑天愉) YIN-SHUANG AI (艾印双)
Institute of Geophysics, Chinese Academy of Sciences, Beijing 100101, China

Abstract

Inversion for the seismic fault rupture history is an important way to study the nature of the earthquake source. In this paper, we have selected two Taiwan earthquakes that occurred closely in time and located in the same region, inversed the distribution of the slip amplitudes, rakes, risetimes and the rupture times on the fault planes by using GDSN broad-band and long-period records and the adaptive hybrid global search algorithm, and compared the two events. The slip rate of every subfault calculated provides information about the distribution of tectonic stress and fault strength. To the former event \((M_s=6.0)\), the maximum slip amplitude 2.4 m and the minimum risetime 1.2 s are both located at the hypocentre. The latter earthquake \((M_s=6.6)\) consisted of two subevents and the second source has 4 s delay. The maximum slip amplitude 0.9 m located near hypocentre is corresponding to the minimum risetime 1.4 s, and the corresponding maximum slip rate 0.7 m·s\(^{-1}\) is similar to the peak value of other large slip rate areas. We consider that the latter event has more complicated temporal-spatial distribution than the former.

Key words: inversion the finite fault rupture history hybrid global search algorithm Taiwan earthquake

Introduction

To determine the seismic fault rupture history by using waveform inversions had been undertaken since the beginning of the 1980s. From that time, a large number of research papers have demonstrated the continuous improvement in this field (Olson, Aspel, 1982; Das, Kostrov, 1990; Langer, Hartzell, 1996). Near-field strong-motion data set have formed the basis of a number of previous studies (Wald, 1990; Kakehi, Irikua, 1997) because more of the fault rupture details can be gained from it. However, Hartzell and Heaton (1983) have demonstrated that dislocation models obtained from teleseismic body waves alone are consistent with ones obtained from local strong ground motion data, therefore, it was feasible to study the earthquake source by using teleseismic data alone due to the lack of good local instrument coverage. The iterative linear least squares method was widely utilized (Cohee, Beroza, 1994) because of its fast speed and complete error estimation. The disadvantage of this approach lies in that it is prone to be trapped into local extremum of the objective function. Though there are lots of papers in this field, using different data and methods, different results would be obtained for the same earthquake (Cohee, Beroza, 1994; Hartzell, Liu, 1996). Wald (1990) had ever studied coseismic slip of two large earthquakes occurred in Mexico by means of linear inversion of teleseismic body waveforms. But, inversion

* Received June 29, 1998; revised August 18, 1998; accepted August 18, 1998.
for fault rupture history is a nonlinear problem and only slip distribution maybe not enough to explore the source process.

In this paper, the May 23, 1994 Taiwan earthquake ($M_s=6.0$) and the May 24, 1994 Taiwan earthquake ($M_s=6.6$) are analyzed because of their near occurrence time, same region and available digital data for several stations in the required epicentral distance range. We also used a newly developed hybrid global search algorithm (Ai, et al, 1998) to inverse the finite fault rupture history, by which we can find the global optimal solution. Taiwan region is located at the boundary of the Eurasian Plate and the Philippine Sea Plate, and is one of the most seismic active region in the world. The comparison of the point source result and the slip distributions, rakes, risetimes and rupture times on finite fault between the two events will help us further understand the tectonic setting of this region.

1 Data and method

The collision and subduction between the Eurasia Plate and the Philippine Sea Plate causes high seismicity in Taiwan and its neighboring area. A moderate earthquake ($M_s=6.0$) occurred in Taiwan region ($23.96^\circ$N, $122.58^\circ$E) (HRVD) on 05:36:6.6, May 23, 1994 and on 04:00:47.8, May 24, 1994 another earthquake ($M_s=6.6$) occurred in the same region ($23.94^\circ$N, $122.43^\circ$E) (HRVD). In this paper, we named these two earthquakes for TW23 and TW24. The tectonic setting of the region where the two earthquakes occurred is shown in Figure 1a. The area from Ryukyu trench through Taiwan to Luzon contains the most complex tectonic structure in the boundary between the Eurasian Plate and the Philippine Sea Plate. The relative motion of the Philippine Sea Plate to the Eurasian Plate is toward the northwest. East to Taiwan, the oceanic floor of the Philippine Sea Plate subducts beneath the Ryukyu arc running along the Eurasian Plate; south to Taiwan, the Philippine Sea Plate including the Luzon arc overrides the Eurasian Plate including the South China Sea. The two earthquakes occurred in the northeast part of Taiwan where most earthquakes were caused by the compression and collision (Zheng, Yao, 1994).

![Figure 1(a)](image)

*Figure 1(a)*  The tectonic setting of Taiwan and its neighboring regions. The asterisks indicate the epicenter of the two events (Modified from Ho, 1986)

![Figure 1(b)](image)

*Figure 1(b)*  The aftershock distribution for the TW23 and TW24 earthquake

The circles and stars represent the aftershocks and epicentral locations of the two mainshock, respectively. The TW23 event located at the left-up of the figure