Coseismic displacement of the 2010, Mw 7.8 Mentawai earthquake obtained from strong motion data

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ABSTRACT

We recover the static displacement by double integration of strong-motion accelerometric data. A baseline correction is applied to prevent numerical instabilities in the double integration and hence unrealistic displacements. We adopted the method of baseline correction introduced by Iwan et al (1985) and modified by Wu and Wu (2007), which is based on the flatness idea. In order to allow analysis of the waveforms in near real-time, we modified the method to obtain the time points that indicate maximum flatness automatically. Our modification can speed up the procedure of baseline correction.

We applied the technique to data of the 25 October 2010, Mw 7.8 Mentawai earthquake. The digital strong motion accelerograph network installed in Indonesia produced the data set from this earthquake. In fact, this is the first large "tsunami earthquake" recorded by this network since it was installed. These data offer the opportunity to calculate the coseismic displacement of the Mentawai earthquake. For this earthquake, displacements of up to 53 cm were derived. The method appears to be stable enough to be applied in an automated fashion in near real-time. A near real-time determination of static displacement could potentially provide crucial information to assess the tsunami hazard very early after the earthquake occurrence.

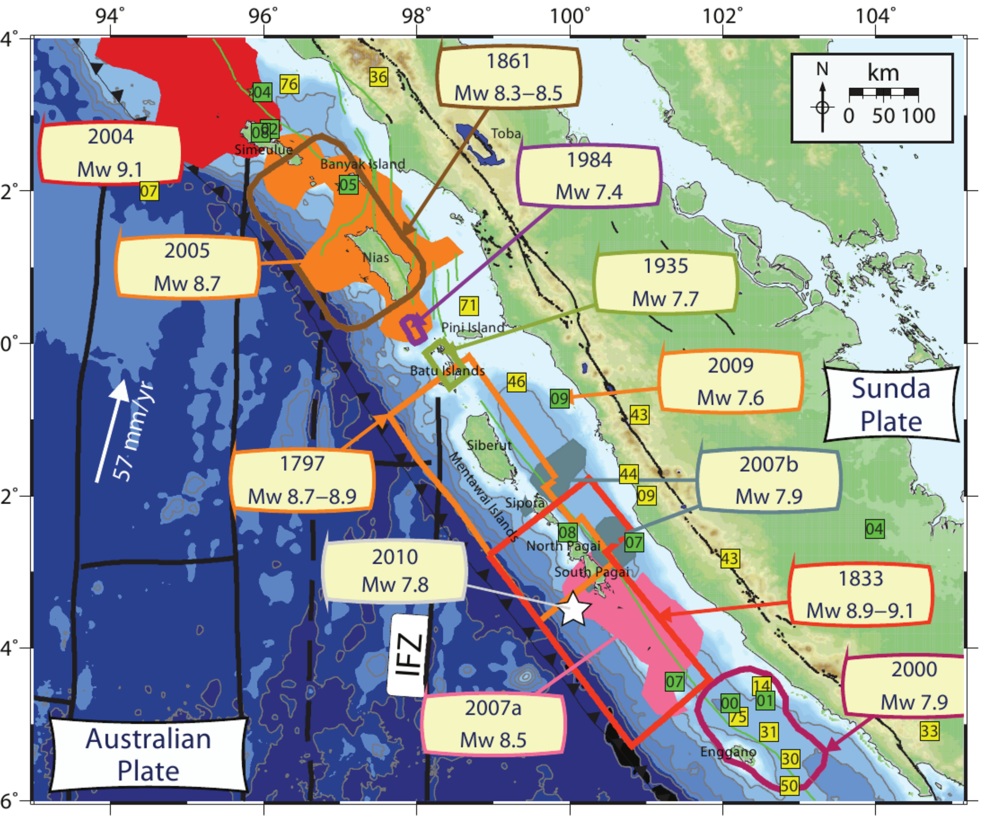

Fig. 1 Map showing tectonic setting of Sumatra. Yellow and green squares indicate historical earthquakes with M≥7 from Newcomb and McCann, 1987 (1903-1984) and NEIC catalog (1985-present), respectively (number in squares indicate year). White star indicates the 2010, Mw 7.8 Mentawai earthquake (modified from Lange et al, 2010)

INTRODUCTION

The displacement can be obtained by a double integration of the acceleration data in time. First integration yields the velocity. However, very often the double integration applied to uncorrected acceleration data will produce unrealistic ground displacements (Figure 2).

This problem arises because of baseline offsets in the acceleration data. Boore (2001) indicated that baseline shifts/offsets occur due to tilting or rotation of the ground during strong shaking.

A small shift in the acceleration baseline will have a profound effect on the final displacement. Therefore, a baseline correction must be applied in most cases to get a realistic displacement (Wu and Wu, 2007).

The method proposed by Wu and Wu (2007) is relatively robust with their "flatness" idea. They calculate and observe the flatness of displacement trace. This method is a modification from the previous one introduced by Iwan et al (1985). However, their procedure is determined by arbitrary choice of flatness in a recursive process (Chao et al., 2010). There is no clear prescription when the iterative scheme of the method should be stopped (Rupakhety et al, 2010).

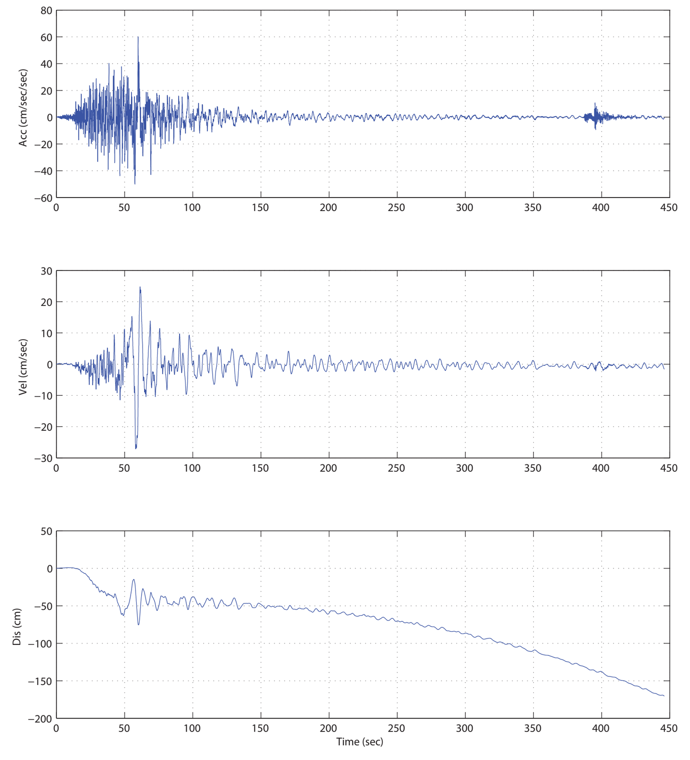

Fig. 2 Unrealistic displacement produced by double integration of uncorrected acceleration data of the 2010, Mw 7.8 Mentawai earthquake from station PPSI (NS-component).

We optimized by an automatic method to find the time points which indicates maximum flatness. This approach allows processing near real-time. A near real-time determination of static displacement could potentially provide crucial information to assess the tsunami hazard very early after the earthquake occurrence.

We applied the technique to strong motion data of the 25 October 2010, Mw 7.8 Mentawai earthquake to calculate the coseismic displacement.

DATA

For this study, we use the strong-motion accelerometric data from Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG). In total, 105 accelerometers have been deployed until the end of 2010, covering the area prone to large earthquakes in Indonesia. It will be increased to 500 stations in 2014. Several stations are operated in collaboration with GFZ-Potsdam and other foreign institutions.

We collected the data of the 2010, Mw 7.8 Mentawai earthquake. 32 waveforms from 11 stations have been used in this study. Despite only a few stations being close to the epicenter, we still see significant coseismic displacement at a number of stations.

METHOD

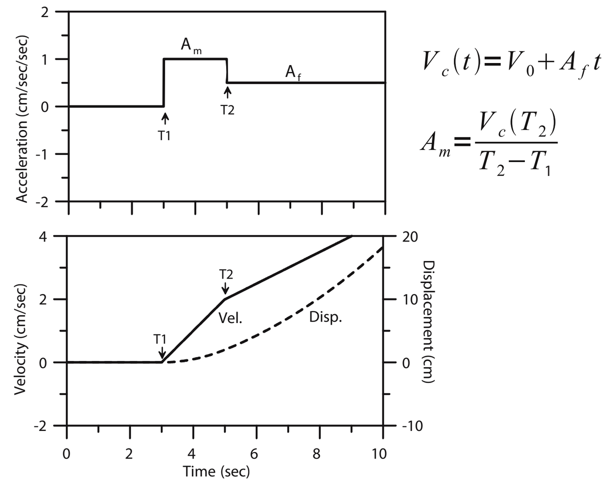

Fig. 3 Simple algorithm for baseline correction (Iwan et al., 1985)

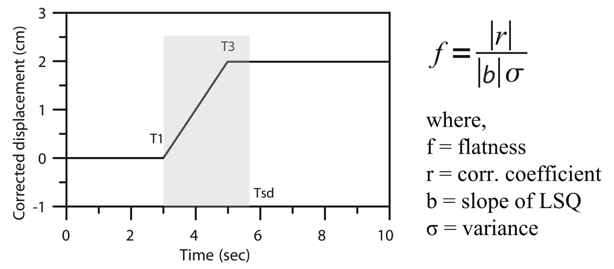

Fig. 4 Flatness parameter applied to determine the corrected displacement. Grey box showing iterative time window (modified from Wu and Wu, 2007)

Based on the method described by Iwan et al. (1985) (Figure 3), Wu and Wu (2007) proposed a new approach using the flatness parameter. They proposed a method using time points T3 to help indicating the maximum flatness of the displacement trace. Related to this procedure, according to Wu et al. (2006a,b) after the ground approaches the permanent displacement position, the corrected displacement trace should be very flat (Figure 3). However, Chao et al. (2010) and Rupakhety et al. (2010) criticized that the time points in their correction procedure are determined by an arbitrary choice in a recursive process. There is no clear prescription when the iterative scheme of the method should be stopped.

Processing steps (modified from Wu and Wu, 2007):

1. Remove pre-event mean from accelerogram.
2. Integrate to velocity and displacement.
3. Choose T1 and Tsd.
4. Apply tentative T3 moves from T1 to Tsd iteratively.
5. Make baseline correction in velocity record using the method described by Iwan et al (1985) by taking as T2 every time point from T3 to the end of the record. Determine f-value in corrected displacement record. Choose time point with a maximum f-value as "tentative selected T2"
6. A final T2 (T2f) is selected from "tentative selected T2" that has the maximum f-value.
7. Make baseline correction using T1 and final T2.

We modify the method to obtain the flatness value automatically. This can be done iteratively by applying tentative T3 moves from T1 to the point when the ground signal has reached its stable permanent displacement position (Tsd). From our observation, this time point is not critical for the final displacement. The tentative T3 moves with a certain interval. Each time it moves, yields one selected T2 with the maximum flatness of displacement trace. We propose T3f (T3-flat) as T3 which produces T2 with the maximum of maximum flatness value of displacement trace. This T2 called T2f, as a final T2. The advantage of this modification of the method is that the flatness value is observed from the whole trace instead of part of the trace. The baseline correction can be done by an automatic process and it can speed up the procedure to be done in near real-time.

RESULTS

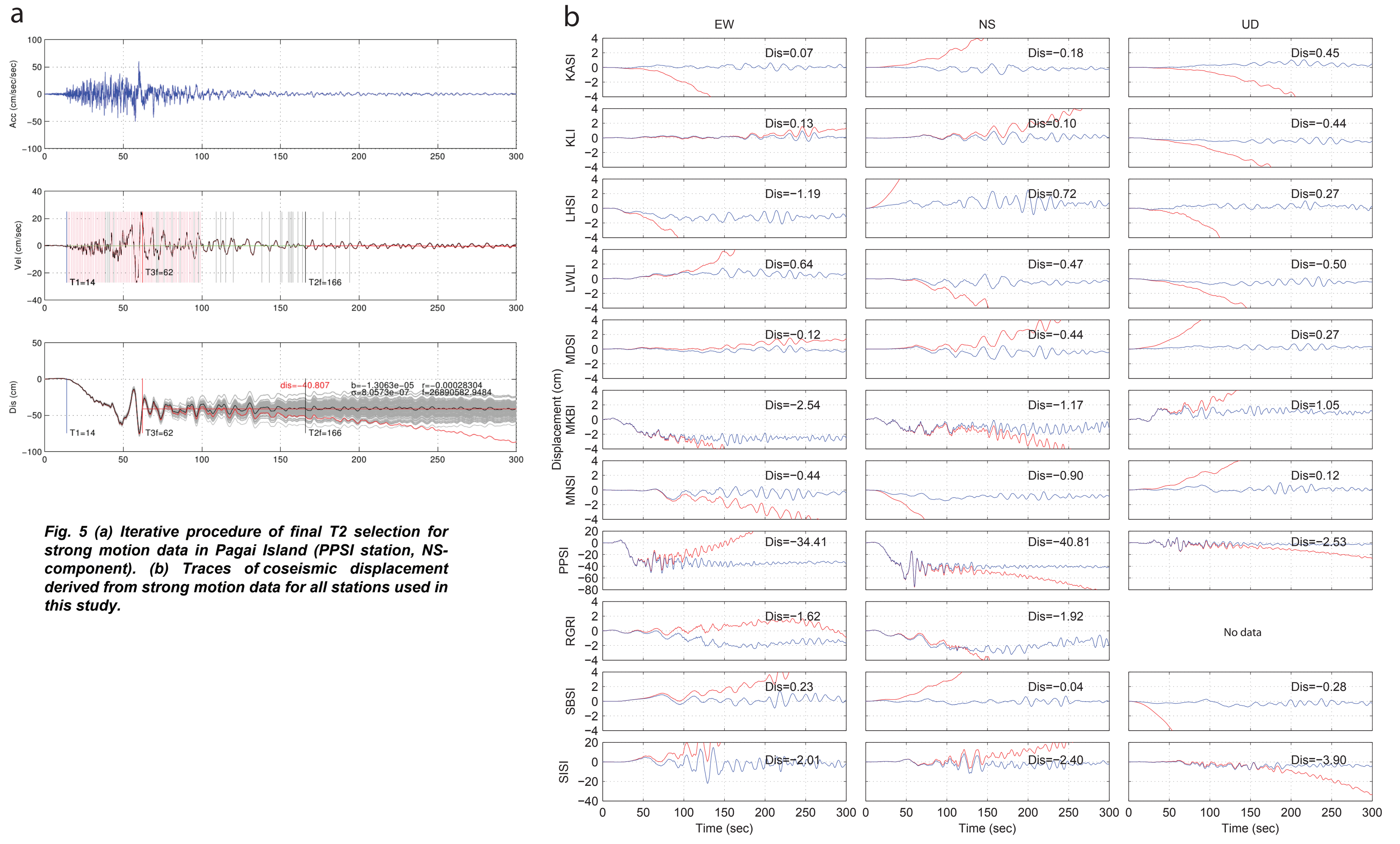

Fig. 5 (a) Iterative procedure of final T2 selection for strong motion data in Pagai Island (PPSI station, NS-component). (b) Traces of coseismic displacement derived from strong motion data for all stations used in this study.

RESULTS

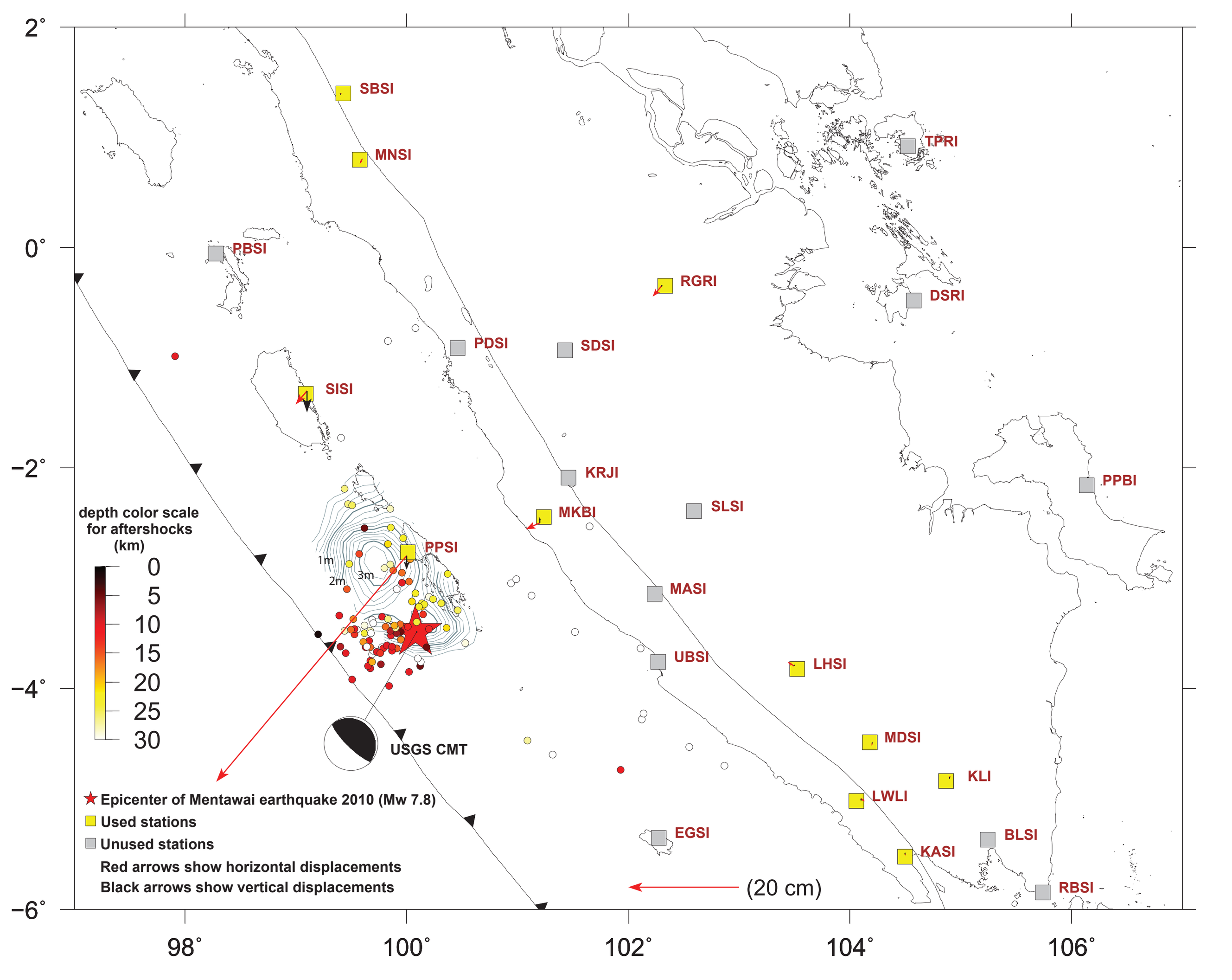

Fig. 6 Map showing coseismic displacements obtained from the strong motion data. Color scaled circles indicate the aftershocks until March 25, 2011 from GEOFON. Contour lines represent the slip distribution from Lay et al (2011).

One station in Pagai Island (PPSI) is located close to the epicenter at a distance of 120 km. From this station we obtain a static displacement of about 53 cm in the southwest direction and minor subsidence (Figure 6).

Stations MKBI in Sumatra Island and SISI in Siberut Island are located at the epicentral distances of about 200 km and 300 km, respectively. However, these stations show the displacement much lower than what it shown in Pagai Island. The static displacements at these two stations are less than 4 cm.

Other stations which are located far away from the epicenter, show the static displacement less than 2 cm.

ACKNOWLEDGEMENT

This study has been supported by Helmholtz Center Potsdam GFZ German Research Center for Geosciences and Meteorological, Climatological and Geophysical Agency of Indonesia (BMKG). We thank to Wijayanto, I Nyoman Sukanta, Horst Letz and Muhammad Hidayat for providing the strong motion data. We also would like to thank Mingpei Jin, Mitja Bartsch, Carsten Falck and Tilo Schöne for the discussion.

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