Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

Multi-event inversion analysis for simpler representation of source mechanism

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ABSTRACT: Several inversion techniques have been recently developed based upon analysis of seismic records at several different sites to obtain displacement or moment distributions on the fault plane as well as rupture process. In these methods, the fault is divided into many grid elements and the source time function of the fault displacements of each element is assumed as simple ramp function with different rise time and displacement.

In this paper, instead of assuming many grid elements of simple characteristics, we introduced event elements which may be considered as to represent the effects of a group of the grid elements related with the event. Each event element is characterized by 7 parameters of modified ramp function. We applied this inversion method to 1980 Izu-Hanto-Toho-Oki earthquake and obtained a result of source model with only three sub-events.

Event inversion analysis presents earthquake faulting process with only several sub-events of asperity instead of the many grid elements. This multi-events inversion technique will not only give simpler presentation of the physical model of complicated faulting mechanism and but also result in easier modelling of fault simulation for earthquake engineering.

1 INTRODUCTION

It is believed that asperity of fault is one of the main mechanism to give strong effect on short period range of earthquake waves. Many inversion analyses have been reported to obtain the distribution and the intensity of the asperities on the fault based upon meshed segments of the fault and simple source time function for a segment.

When we need to predict ground motion by empirical Green's function summation method, we have to assume distributions of rupture starting time and released moment for each fault element which is rather difficult because of many possibilities.

We may separate the movements of large earthquake fault into several energy released events or asperities rather than many meshed elements. Each event may be equivalent to a group of the meshed element. Source time function for these events may require more sophisticated characteristics than simple ramp function which is assumed for grid element presentation.

It is not only useful for engineering but also easy to understand the fault mechanism if a large earthquake can be divided into several(2 or 3) smaller asperities through some characteristic model.

In this paper, we propose a new inversion method. it is based on the assumption that large earthquake is an assembly of several smaller asperities, and each asperities have simple source mechanism.

2 SOURCE MODEL FUNCTION

Most inversion analyses assume a very simple source model such as ramp function to represent movement of small meshed fault elements. On the other hand, the multi-event model may require more special characteristics of source time function which represent group of the elements.

Figure 1 is the comparison between the meshed fault elements and multi-events presentation of the faulting mechanism. Time rate of the moment release ($\dot{M}(t)$) for the meshed elements is squared function. The corresponding function for the event presentation may require to have more refined expressions on the slope of

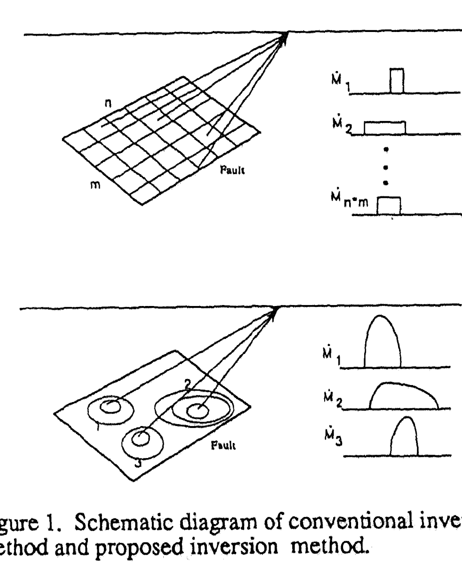


Figure 1. Schematic diagram of conventional inversion method and proposed inversion method.

the moment rate increase, the time corresponding to reach the maximum moment rate and the slope of moment rate decrease.

In this paper, we adapted the following function as a first order approximation as the source time function of an event at an asperity.

$$M(t) = \alpha\left(\frac{t}{\alpha}\right)^{\delta} \qquad \{0 \le t \le \alpha\}$$

$$M(t) = 1 - (1-\alpha)\left(\frac{1-t}{1-\alpha}\right)^{\delta} \qquad \{\alpha \le t \le 1\} \qquad (1)$$

where,

M(t); released seismic moment normalized as the maximum value of 1.

t; elapsed time normalized by duration time.

alpha and delta; shape parameters of moment rate time function.

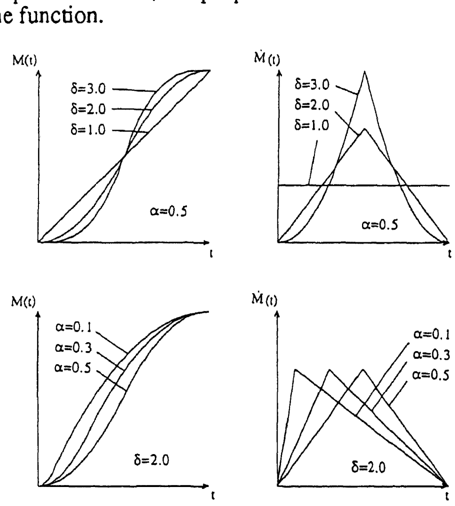
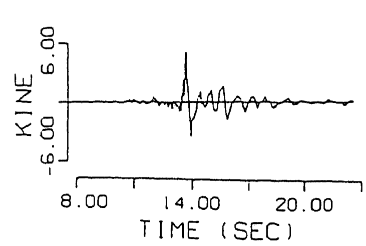
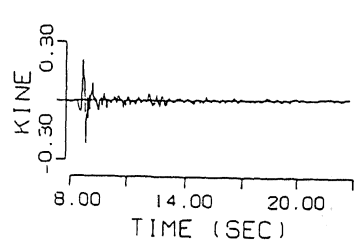


Figure 2. Shape of proposed source time function.



(a) Magnitude 6.6 event on Apr. 4th 1987.



(b) Magnitude 4.6 event on Feb. 25th 1984.

Figure 3. Velocity waveform at Tomioka site.

The shape of the function and effects of shape parameters are shown in Figure 2. If delta is 1.0, the function M(t) becomes a simple ramp function. As delta increases, the shape of the function $\dot{M}(t)$ becomes sharper triangle. Alpha determines the elapsed time when the $\dot{M}(t)$ becomes at its maximum.

We show a case study to estimate the source function for an event based upon comparison between two earthquakes of magnitudes of 4.6 and 6.6.

Figure 3(a) shows the velocity waveform of NS component at GL-950m, which was observed at Tomioka, Ibaraki Prefecture, by an event of April 4,

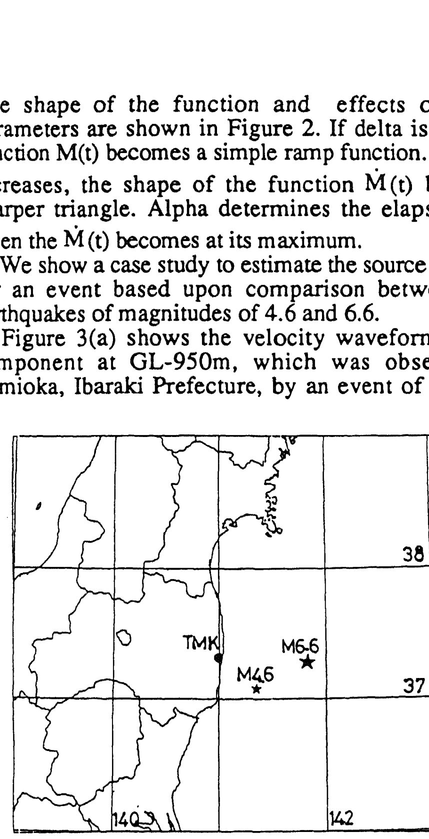
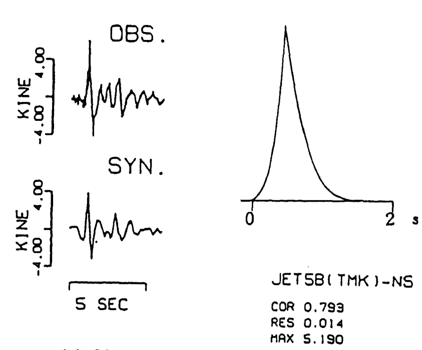
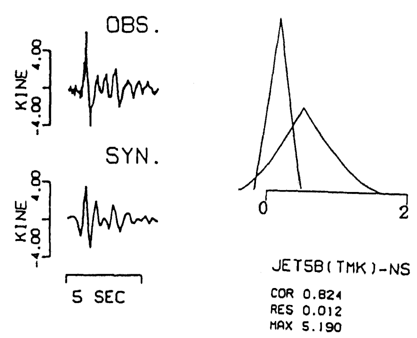


Figure 4. Location of Tomioka site and epicenters of the events used in the study.



(a) Single event model.



(b) Double event model.

Figure 5. Simulating results of the magnitude 6.6 event by the proposed inversion method.

1987 Magnitude 6.6 in Pacific ocean. Figure 3(b) was obtained at the same site by a small earthquake of Feb. 25th 1984 of magnitude 4.6. The location of the epicenters and Tomioka site are shown in Figure 4.

Assuming the record from the earthquake of magnitude 4.6 as the empirical green function from the source region to Tomioka-site, the inversion analysis was applied to the event of earthquake of magnitude of 6.6 based upon the source function of eq.(1).

Figure 5 shows the results of the inversion analysis. The figure shows two cases, (a) is single event and (b) is double event model. In the figure, the obtained source time functions are shown in the right hand side and the comparisons between the simulated and observed records are also shown in the left hand side.

Correlation between the observed and the simulated is 0.793 for single event and 0.824 for double event model. The source function of the single event model shows the shape of the moment release rate is similar to an isosceles triangle. The source function of the double event model suggests the second asperity is the same shape as the single event and represents the main phase of the simulated waveform. The first asperity of double event model simulates the later phase or longer period. Single event model, though a slightly smaller value of the correlation compared to the double event one, shows well correspondence to the general waveform characteristics of the observed one.

3 INVERSION OF 1980 IZU-HANTO-TOHO-OKI EARTHQUAKE

This method is also applied to 1980 Izu-Hanto-Toho-Oki earthquake with magnitude 6.7. Figure 6 shows the location of epicenter and seven recorded stations used in this analysis.

Fukuyama and Irikura (1989) analyzed this earthquake using 5x5 meshed fault. As they determined 3 parameters (rupture starting time, rise time and released moment) per sub-fault, 75 parameters had been finally identified.

In our analysis, we have to identify seven parameters per sub-event, i.e., rupture starting time, the released moment, source duration time, source function parameters alpha and delta, and position parameters on fault L and W. The Inversion technique and the records as well as empirical green's function were the same as Fukuyama and Irikura (1989) except source time function.

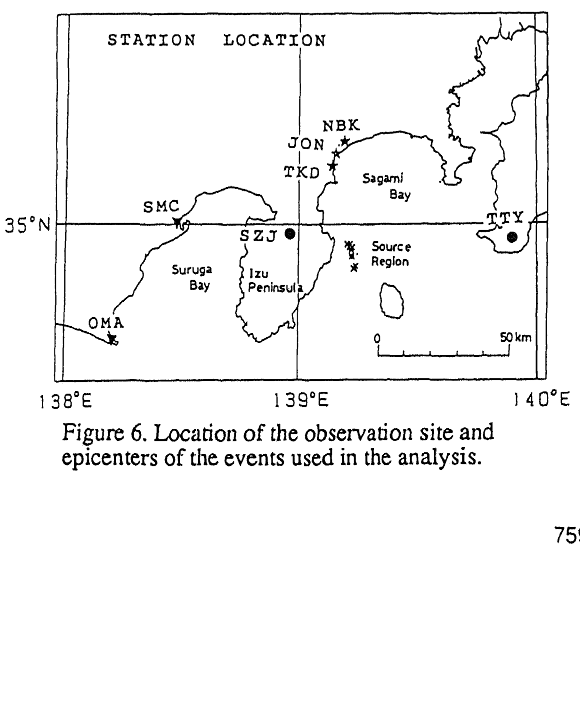


Figure 6. Location of the observation site and epicenters of the events used in the analysis.

We found that three events model can reasonably simulate the general characteristics of the earthquake records. The detail information of the seven parameters for three asperities is listed in Table 1 and shown in Figure 7.

Figure 8 shows the comparison of the recorded velocity at seven sites and the simulated result of the proposed method. Correlations are from 0.389 to 0.800 and a bit lower than the values by Fukuyama and Irikura(1989) which ranged from 0.497 to 0.875. However, we obtained agreeable results at the most station.

Table 1 Source parameters obtained.

	sub-event 1	sub-event 2	sub-event 3
rupture time(sec)	0.5324	0.0878	0.9078
moment(dyne cm)	3.036E+24	5.727E+24	4.902E+24
duration time(sec)	1.8795	1.0638	1.5073
delta	3.8789	1.2589	1.0266
alpha	0.3796	0.6608	0.2644
L (km)	-5.0285	1.1103	4.8971
W (km)	0.4326	0.1824	0.0024

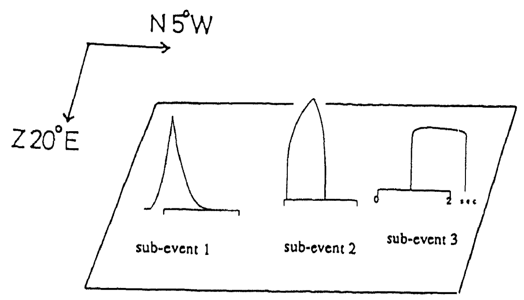


Figure 7. Source image of 1980 Izu-Hanto-Toho-Oki earthquake obtained by the proposed method.

4 CONCLUSION

1)The proposed multi-event inversion will give much simpler presentation of the source process on the fault compared to the grid divided fault element inversion.

2) Further case studies on many earthquakes of other types shall be required to find typical patterns of source function of asperities to simulate the earthquake ground motion based upon fault source mechanism by several sub-events.

ACKNOWLEGEMENT

Authors thanks to Prof. K. Irikura, Disas. Prev. Res. Inst., Kyoto University, for useful discussions through the research. We also thanks to Dr. E. Fukuyama, National. Res. Inst. for Earth sci. and Disas. prev., for opening the original computer program for inversion analysis used in the research. Part of seismic records were observed by the joint research study on electric power companies in Japan,

entitled "Study on the characteristics of seismic wave". Other seismic records were observed by Earth. Res. Inst., Univ. of Tokyo, Gifu Univ. and Kyoto Univ.

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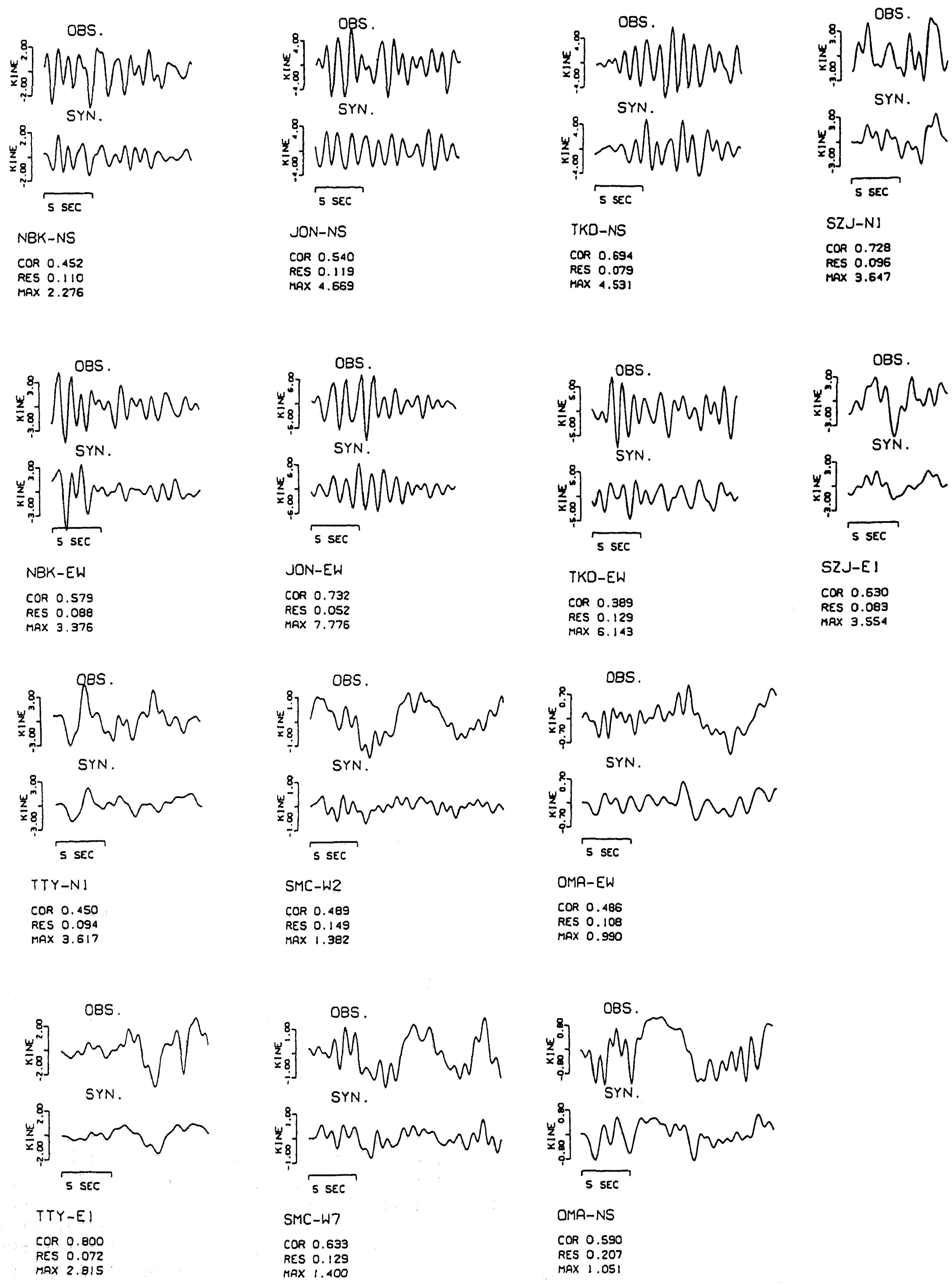

Figure 8. Comparison of the observed and the simulated obtained by the proposed method.