Fast Estimation of Source Parameters

Application to Shallow Earthquakes

Charléty, J. and Vallée, M.

Université de Nice Sophia-Antipolis, laboratoire Géoazur

CNRS - IRD

charlety@geoazur.unice.fr

Abstract

We develop a new methodology to rapidly and automatically retrieve the earthquake source parameters: magnitude, focal mechanism, hypocentral depth and source time function.

The P-wave signal duration is estimated by filtering the data within a narrow frequency band centered around 1 Hz. Over this frequency band, only the P-wave train (P, pP and sP) remains. The determination of the source parameters is based on the deconvolution of the Green function. The parameters search is achieved by an exploration of the parameters space. Four to five parameters are inverted: strike, deep and rake of the focal mechanism, depth and if the earthquake is shallow (depth less than 50 km) the seismic velocity.

We tested the method for earthquakes of magnitude larger than or equal to 7.8 and from 1990 to 2009. The obtained results are promising and interesting. We point out the fact that this methodology allows to complete the catalogue of the source parameters by adding the relative source time function at each station. A precise comparison between this new broadband technique and the low-frequency global CMT catalogue is presented.

1. Introduction

We develop a new methodology to rapidly and automatically retrieve the earthquake source parameters: magnitude, focal mechanism, hypocentral depth and source time function.

This project is part of the ongoing effort to develop fast and efficient method to determine the source parameters of earthquake for real-time implementation. Early warning systems based on the real time automated analysis can play an important role in reducing the negative impact of such catastrophic events.

This study presents a methodology able to retrieve magnitude, focal mechanism, hypocentral depth and source time function. For that purpose we use P, pP, sP and SH waves at teleseismic distances.

2. Method

2.1 First step: Signal duration determination

The determination of the time window of signal selected for the deconvolution uses the observations made by Ni et al. [2005] or Lomax [2005] about the P wavetrain at 1Hz. For high frequencies (1-5Hz) only the P wavetrain is not destroyed by the filtering that means that only P, depth phases are still visible 1.

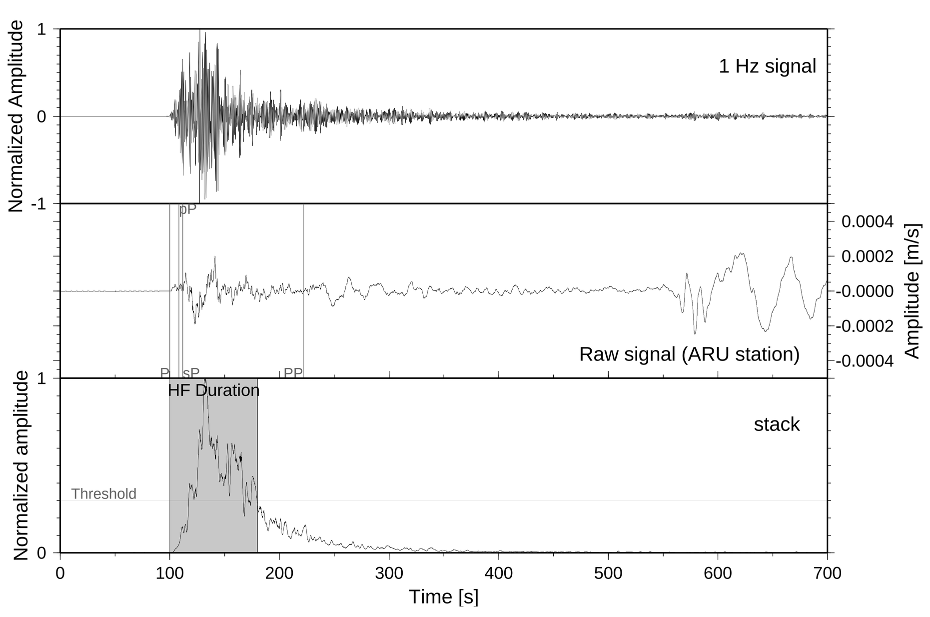

Figure 1: *Illustration of the determination of the signal duration for the deconvolution. Presented the earthquake of Hokkaido, Japan, 2003/9/25 19:50:38, M_w 8.3.*

2.2 Second step: Optimized deconvolution of P- and SH-waves

The parameters space is explored and sampled with the neighbourhood algorithm [Sambridge, 1999]. For each station and given parameters set, the green's function is calculated with the Bouchon's method [Bouchon, 1976] for a simple earth model which is identical for the source and for the receiver. Then the source time function is computed by deconvolving the signal by the green function. The deconvolution algorithm [Vallée, 2004] imposes the causality and positivity of the source time functions. The solution corresponds to the parameters set that give moments defined by the source time function at all stations as stable as possible.

3. Results

3.1 Data

We analyse the data of earthquakes whose characteristics reported on the global CMT catalogue satisfied:

- occurred during the period 1990/1/1 - 2009/3/18
- depth < 50 km
- 45 ≤ tension plunge ≤ 90
- 7.8 ≤ M_w ≤ 8.9

This set of earthquake is supposed to represent the major shallow subduction events. The data are teleseismic signal with epicentral distance of 50°-90° for P-wave and 60°-95° for S-wave. For such distances, the time interval between the (P, pP, sP and PcP) and PP is large enough not to interfere. It implies that the source duration is not too long and thus to discard giant or very complex earthquakes.

Figure 2: *Set of earthquakes analysed in this study. The number corresponds to the one repoted in the following figures. Also shown the comparison between the focal mechanism determined by this new methodology and the one determined by Global CMT.*

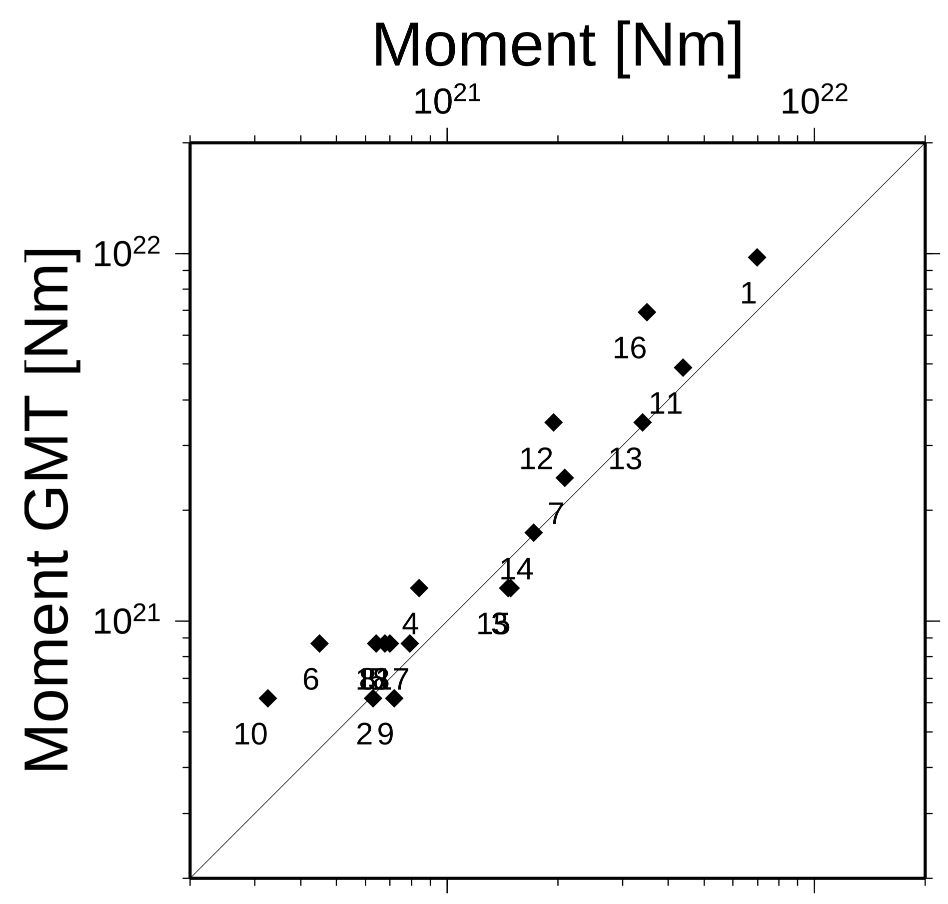

Figure 3: *Moment comparison between the CMT solution and our results. We tend to under-estimate the moment. To know the correspondance between number and earthquake report to figure 2.*

For that kind of earthquake, the amplitudes of surface wave are proportional to $M_0 \sin(2\delta)$, with δ the dip. This can be the cause of some trade off between dip and moment. Therefore for a more robust comparison of the results, we decided to compare the quantity $M_0 \sin(2\delta)$.

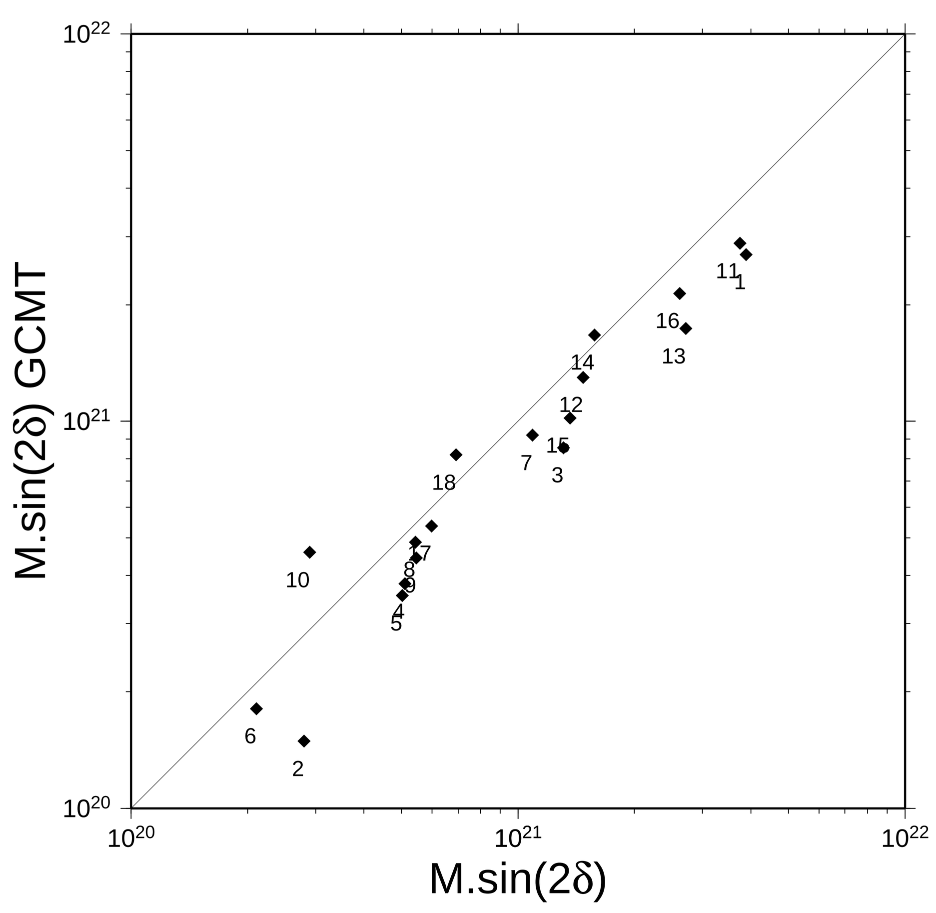

Figure 4: *Comparison of the quantity $M_0 \sin(2\delta)$ between our results and those of GCMT. To know the correspondance between number and earthquake report to figure 2.*

We note that the method tends to over-estimate $M_0 \sin(2\delta)$.

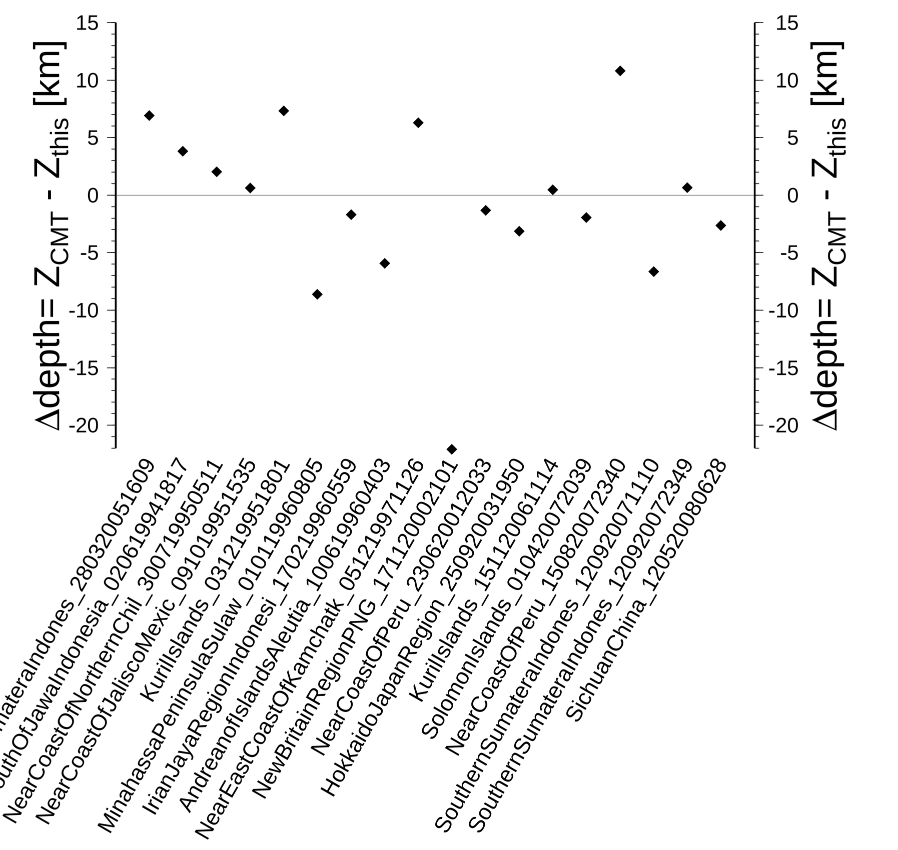

Figure 5: *Comparison of the depth.*

4. Discussion and Conclusion

The results show a good agreement between the results for the determination of the moment or the focal mechanism. We can however note some differences in dip estimation (figure 4).

The depth is similar to the ones determined by Global CMT. Most of the events are within ±5 km. The trade-off between focal depth and the shape of source time function [Christensen and Ruff, 1985] seems to be of little importance. Consequently, it confirms the good behaviour of the method.

The information that we bring is the apparent source time functions derived from the deconvolution. It allows to give some valuable information on the source and can be used for other studies (high resolution tomography, source studies, ...).

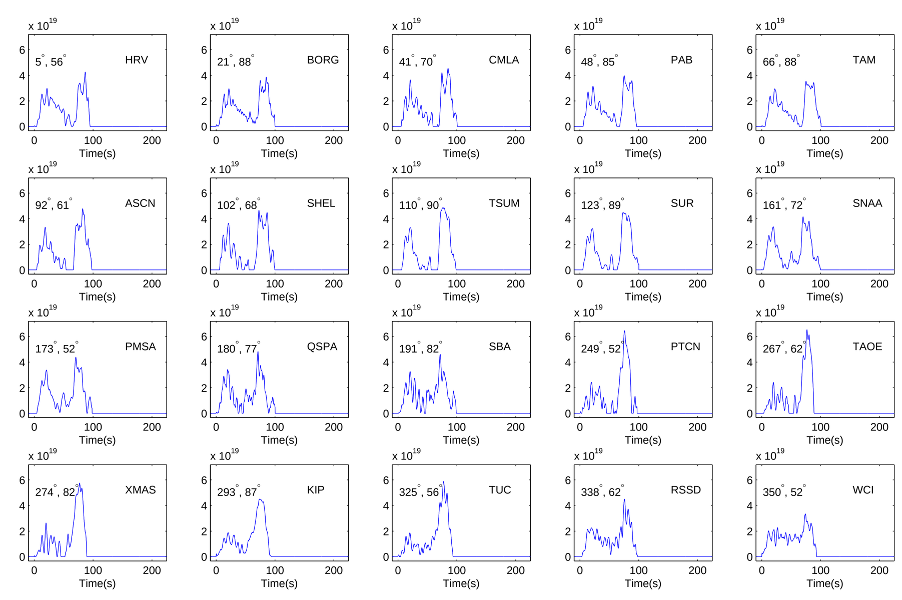

Figure 6: *Example of apparent source time functions obtained from P-wave for the earthquake of 2007/8/15 23:41 Peru M8.0 (number 15). The apparent source time functions show the main features of the source, i.e. a two separated slip patches, the second one occurring 60s after earthquake initiation (cf http://geoazur.oca.eu/spip.php?article107).*

We show that the low frequency content of large earthquakes can be retrieved by body waves analysis.

References

M. Bouchon. Teleseismic body wave radiation from a seismic source in a layered medium. *Geophys. J. R. Astr. Soc.*, 47:515–530, 1976.

D.H. Christensen and L.J. Ruff. Analysis of the trade-off between hypocentral depth and source time function. *Bulletin of the Seismological Society of America*, 75(6): 1637–1656, 1985.

A. Lomax. Rapid estimation of rupture extent for large earthquakes: Application to the 2004, m9 sumatra-andaman mega-thrust. *Geophys. Res. Lett.*, 32:L10314, 2005.

S. Ni, H. Kanamori, and D. Helmberger. Energy radiation from the sumatra earthquake. *Nature*, 434:582–582, 2005.

M Sambridge. Geophysical inversion with a neighbourhood algorithm i. searching a parameter space. *Geophys. J. Int.*, 138:479–494, 1999.

M. Vallée. Stabilizing the empirical green function analysis: Development of the projected landweber method. *Bulletin of the Seismological Society of America*, 94(2): 394–409, 2004.

ERICE 2009, Workshop on real time seismology , 2-9 May 2009, Erice, Italy