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Determining Magnitudes of Large Earthquakes in Japan using Seismic Stations in China

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1. Introduction

Fast determination of earthquake magnitude is of importance for estimating shaking damages, and tsunami hazards in Japan. However, there are problems for accurately estimating magnitude of large earthquakes rapidly. Among many magnitude scales, some saturate for large earthquakes and lead to significant underestimation of earthquake size, such as local magnitude M_L, body magnitude m_b, surface magnitude Ms, and M_{wp}, while other scales like moment magnitude M_w, can give actual results for the size of large earthquakes but require long-period data recorded by broadband seismometers, especially for extremely large earthquakes.

Wang et al. developed a new magnitude scale M_{dt} by considering P wave maximum displacement (D) and source duration (T). We apply this procedure to eleven $M \geq 7.0$ (USGS) shallow earthquakes that occurred in and around Japan from 2008 to 2016. The results agree well with the Mw estimated from W-phase inversions, and suggest that the magnitudes can be accurately estimated in 6 to 12 min after origin times of earthquakes, depending on the epicenter distances to seismic stations in China.

2. Data and method

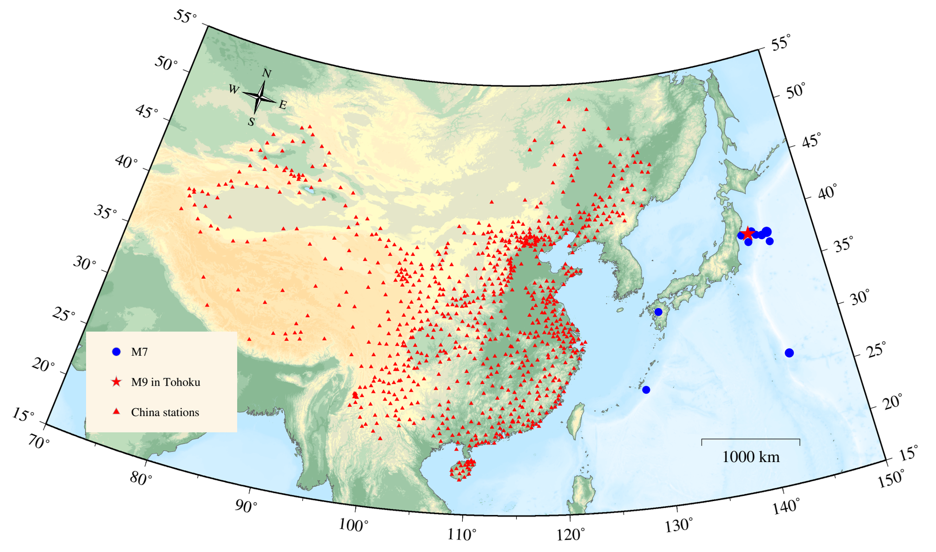
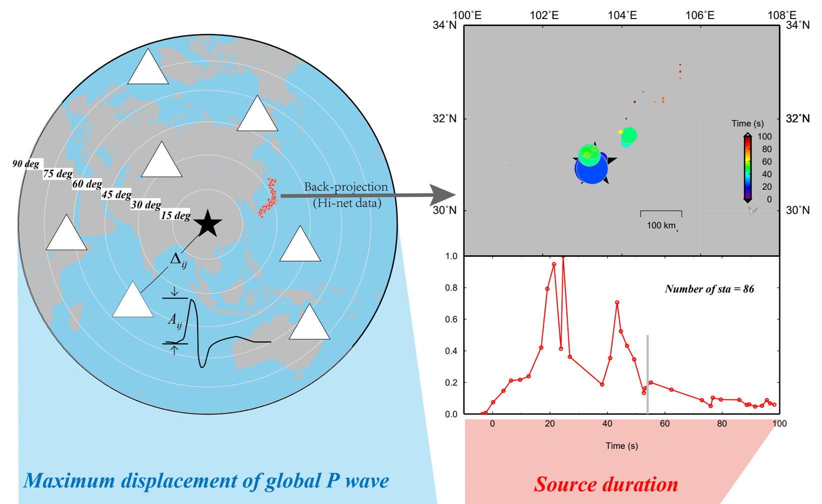


Fig. 1 Distribution of Chineses stations and M>= 7.0 earthquakes in Japan fro 2008 to 2016

Networks: China dense stations
Stations number: ~1000
Channel: BHZ
Distance range: 10 - 60 degree
Azimuth range: 238 - 332 degree

Networks: Global stations
Stations number: > 40
Channel: BHZ
Distance range:10 - 60 degree
Azimuth range: 0 - 360 degree



$$M_{dt} = \frac{0.55}{N}\sum_{i=1}^{N}\log A_i + \frac{0.67}{N}\sum_{i=1}^{N}\log\Delta_i + 1.01\log(T) + 5.55$$

Method:

Step 1: Source duration
Method: Back-projection
Data: China dense stations
Frequency band: 0.05 - 2 Hz
Window length: 10 s
Sampling interval: 0.01s

Step 2: Calculate the maximum displacements of the direct P-wave recorded across the globe

Step 3: Combine earthquake source duration with its P-wave maximum displacement to compute M_{dt}

Fig. 2 Methodology for determining magnitudes of large earthquakes. Magnitude is estimated by combining (a) max-imum displacements of global P wave amplitude and (c) source durations. Here the source duration is estimated by backprojection analyses using a large regional seismic array. The grid line in (c) shows the cutoff where the rupture ends. (b) Color circles indicate the local maximums of the stacked energies. Here Aij is the maximum vertical displacement of the tele-seismic P wave recorded at the ith station for event j, and Δij is the epicenter distance (km). Parameter Tj is the source duration derived from the backprojections, and N is the number of global stations. The operator log denotes the decimal logarithm. (Wang et al., GRL, 2017)

3. Magnitude variation with elapse time for 2011 Mw 9.0 Tohoku earthquake

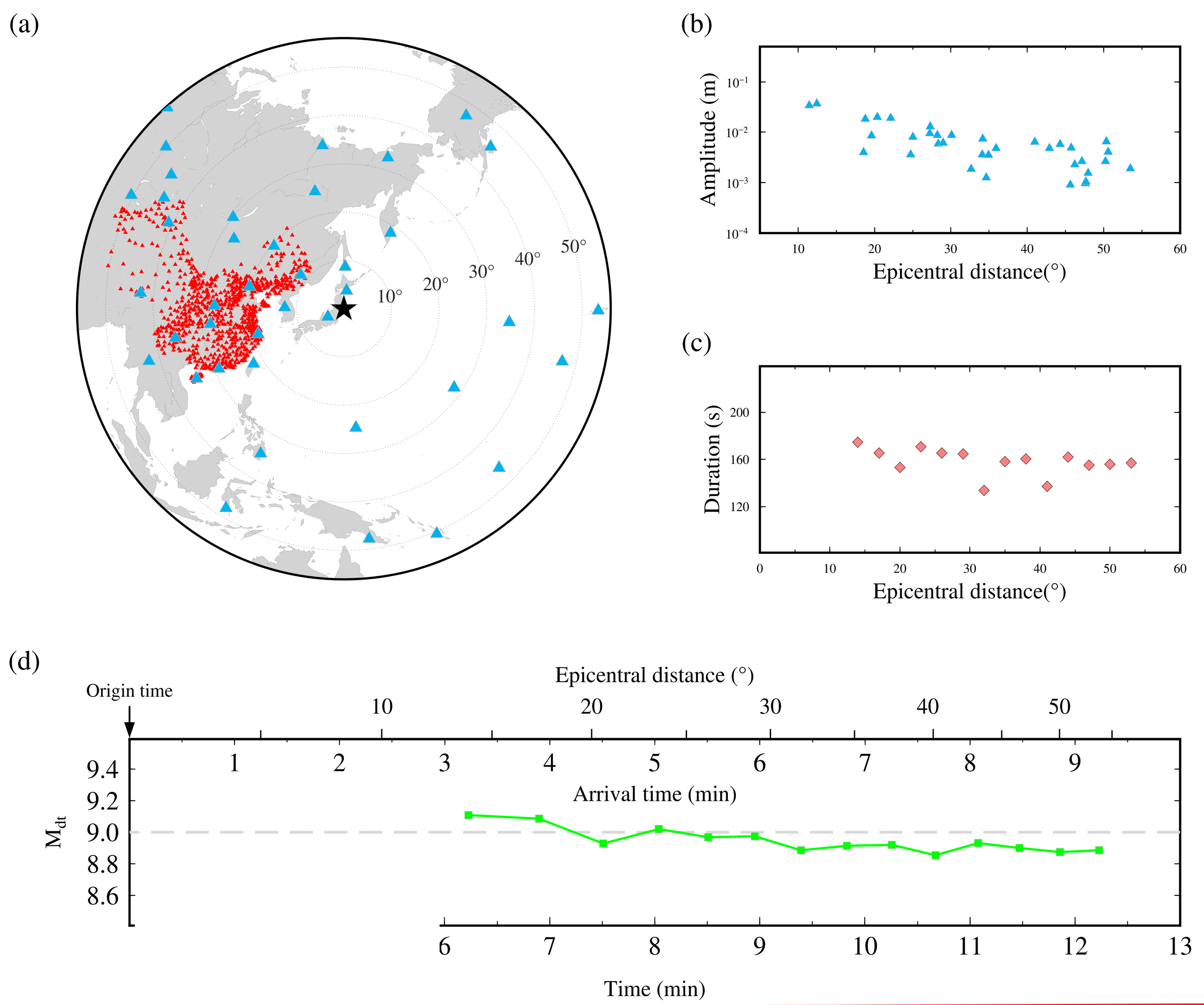


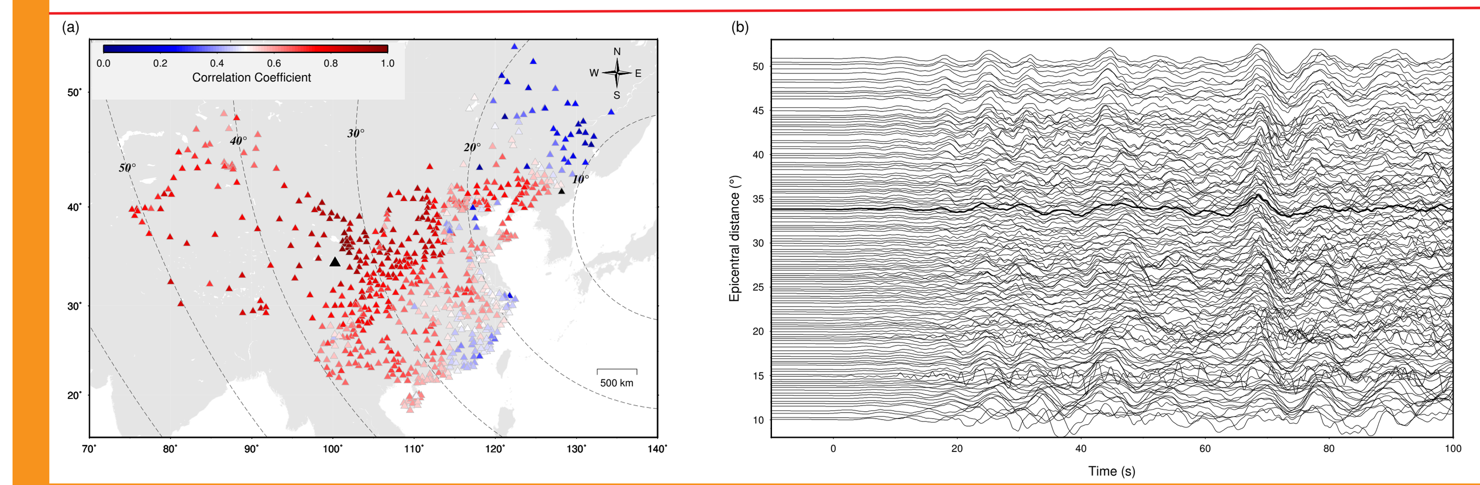
Fig. 3 Determining magnitude of the 2011 Tohoku earthquake using seismic stations in China.

(a). Black star represents location of 2011 M9.0 Tohoku earthquake from USGS. Lightblue and red triangles show distribution of global stations and China stations respectively;

(b). The earthquake's maximum displacement of P direct wave with epicentral distance;

(c). The results of source durations with epcentral distance;

(d). The value of M_{dt} with epcentral distance, arrvial time of the P waves from earthquake original time, and prodcut-ready time, respectively.



Why stations ≥ 30 ° ?

Fig. 4 Seismograms of the 2011 Tohoku earthquake observed at Chinese stations and their similarities.

(a). Triangles represent station locations and black star represents model station. Different colors indicate stations' correlations with model station.

(b). Waveform corresponding with stations in (a); The bold line matches the model station.

Discussion and Conclusion

Using Chinese stations that are at distances of larger than 10 degree, and GSN stations at distances of 10 – 60 degree, we obtained the magnitudes for the 11 earthquakes, which agree well with the moment magnitudes determined from the GCMT and USGS.

The results of station corrections demonstrate that the magnitude of earthquake can be estimated well with the pre-stored database of station corrections without requiring the catalogue information. Therefore, we propose to build an automated system for determining magnitude of large earthquake in and around Japan using real-time seismic data in China and across the globe and a pre-stored database of station corrections, for disaster mitigation right after a damaging earthquake, especially when dealing with the tsunami evacuation and emergency rescue.

4. Results of the 11 large earthquakes

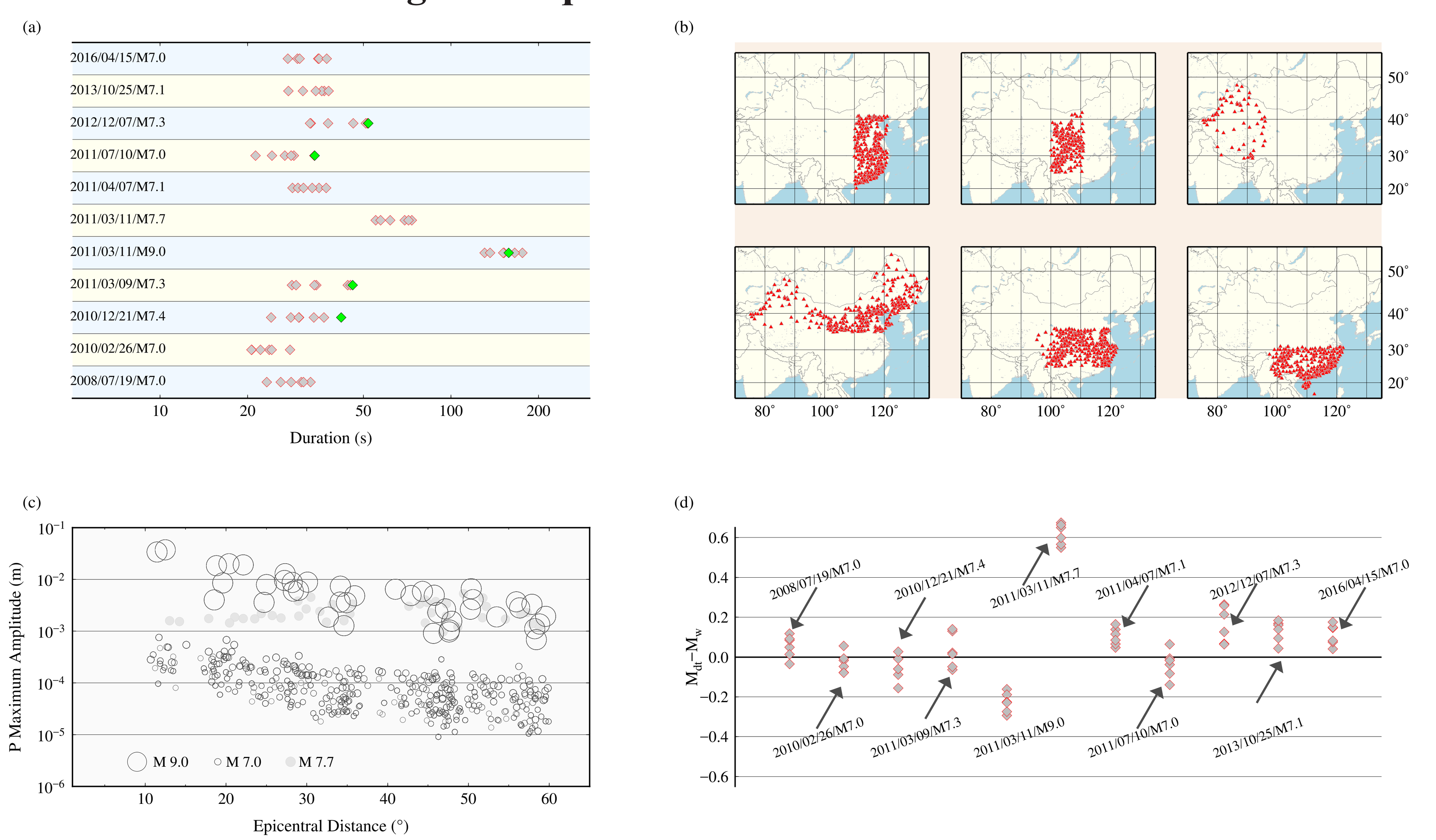
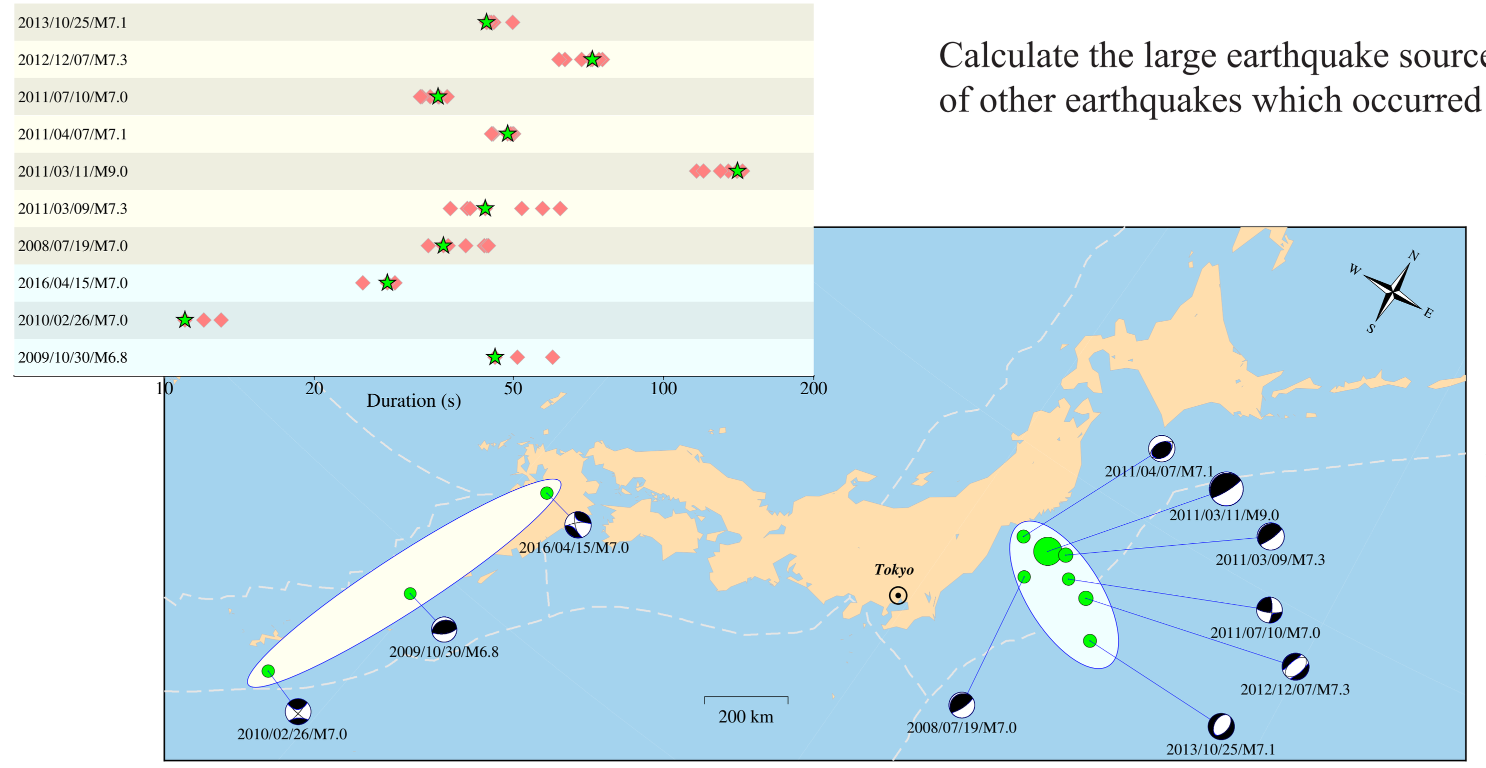


Fig. 5 (a). Source durations for six groups of stations in (b), green diamonds represent energy durations by Convers and Newman [2013];

(c). P wave maximum amplitude with epicenter distance for all of the analyzed earthquakes. Radius represents value of magnitude, while solid and lightgray circles indicate a M7.7 earthquake occurred in 39 minutes after 2011 Mw 9.0 Tohoku earthquake;

(d). Comparison between M_{dt} and M_w for the analyzed earthquakes.

5. Station corrections



Calculate the large earthquake source duration with station corrections of other earthquakes which occurred near the large earthquake.

Real time determination of magnitude and source length of large earthquakes without the requirement of earthquake catalog

Fig. 6 Back-projection using station corrections derived from nearby earthquakes. The earthquakes are sorted into two groups according to their hypocenters. One group is at a small distance from China (left bottom), and the other is including and close to 2011 M 9 earthquake (right bottom). Upper left: Lightred diamonds and green stars indicate source durations derived from back-projected using station corrections from other earthquakes, and itself, respectively.
station corrections, represently.

Acknowledgments

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