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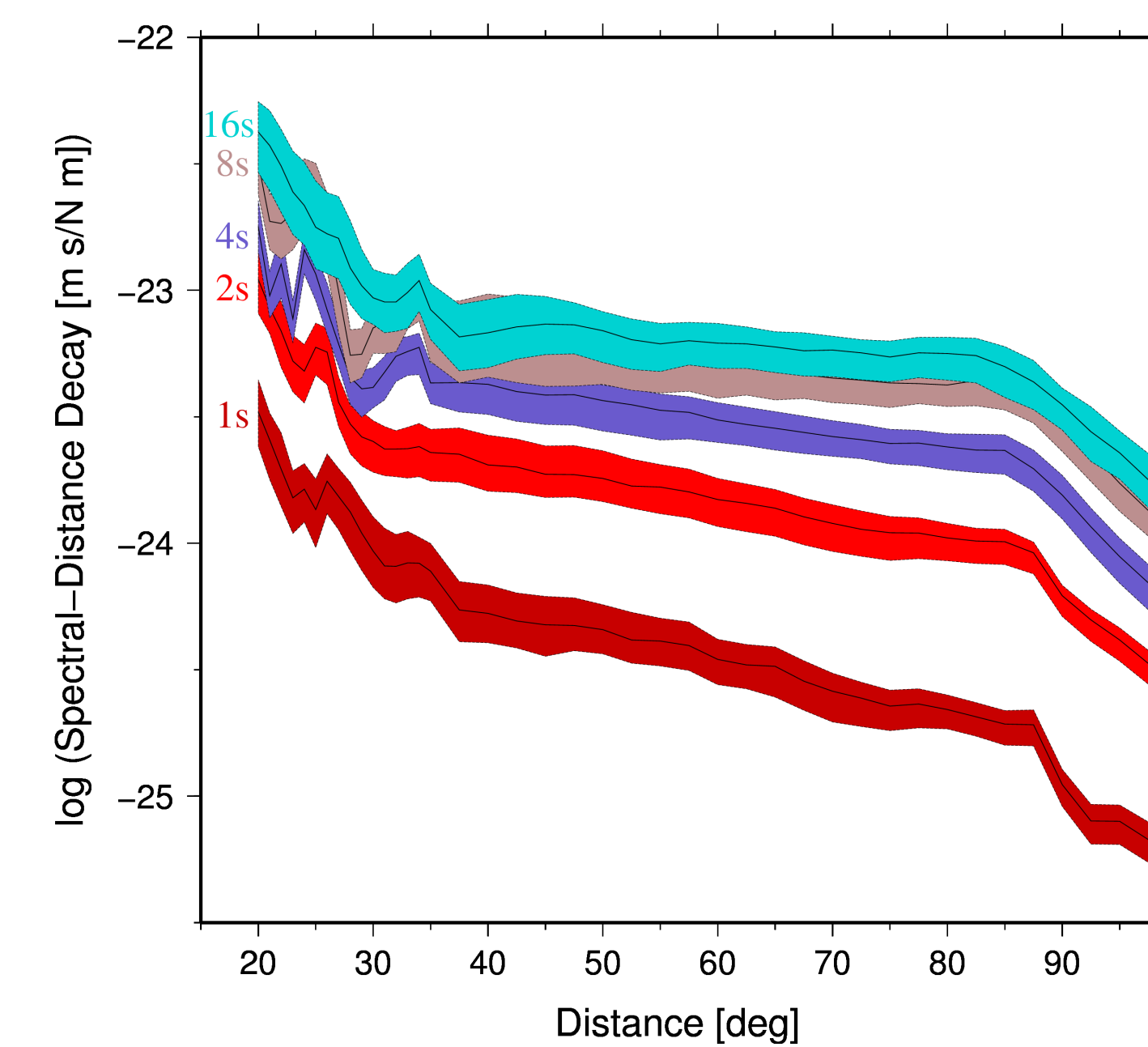
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## Problem and aim

The effectiveness of a rapid response system to strong-great earthquakes is based on the determination in a short-time of the parameters characterizing the seismic event. Besides the source location, the event magnitude, as a measure of the “earthquake size”, is a parameter of fundamental importance. Many magnitude scales have been developed to describe the “size” of a seismic source and each of them gives different information of the characteristics of the earthquake. Among the non-saturating magnitude scales, the energy magnitude  $M_e$  is related to an important physical parameter of a seismic source, i.e. the radiated seismic energy  $E_s$ . Indeed  $E_s$ , being a measure of the high frequency content radiated by a seismic source around its corner frequency, is closely related to the earthquake damage potential. Therefore, our aim is to develop a procedure to determine  $E_s$  and  $M_e$  a few minutes after earthquake origin time (OT) that can be easily implemented in rapid response systems, as required by disaster management organizations to evaluate an earthquake’s damage potential and also to perform loss estimations.

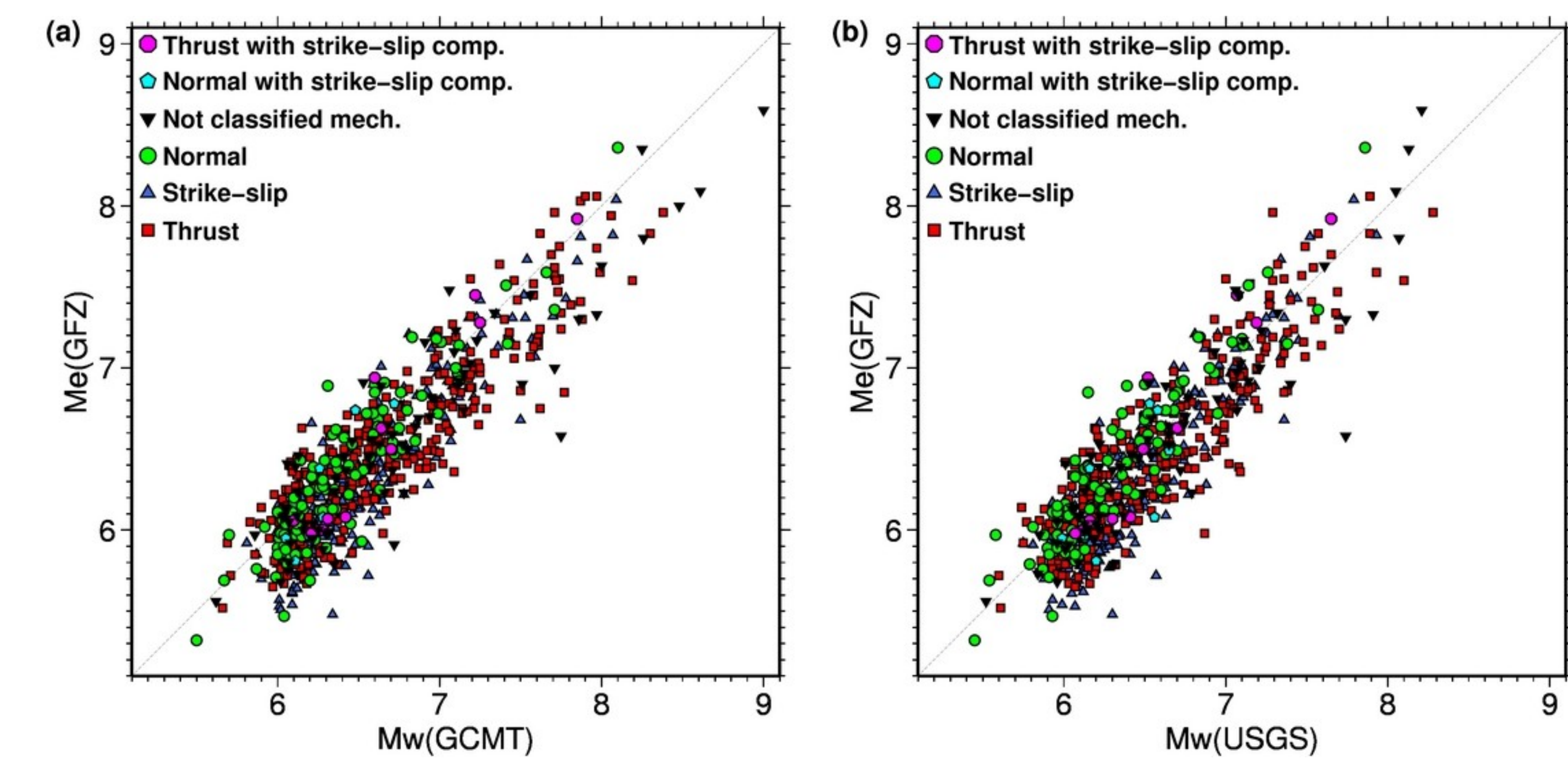
## Correction for the propagation effects

In our study P-waves of teleseismic events within the distance range  $20^\circ \leq \Delta \leq 98^\circ$  are considered. In order to calculate the energy radiated by an earthquake, the energy loss experienced by the seismic waves during propagation must be recovered. The energy decay is frequency-dependent, hence spectral amplitude decay functions for different frequencies must be computed. For this purpose we used numerical simulations of Green’s functions (Wang, 1999) based on the reference Earth model AK135Q. On the right are shown the function between 1 s and 16 s in steps of one octave. These functions allow us to perform the correction for the energy loss during propagation in a rapid and robust way and, therefore, to compute  $E_s$  and  $M_e$  at the single station (for further details see Di Giacomo et al., 2008).



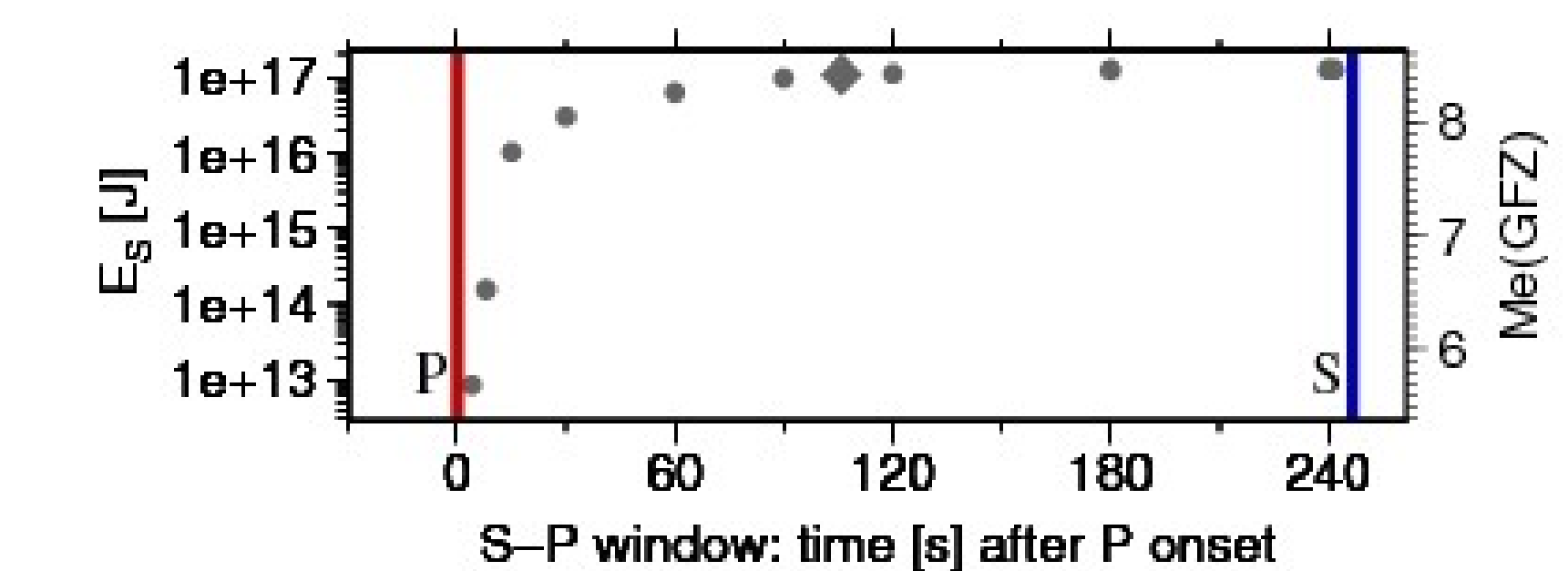
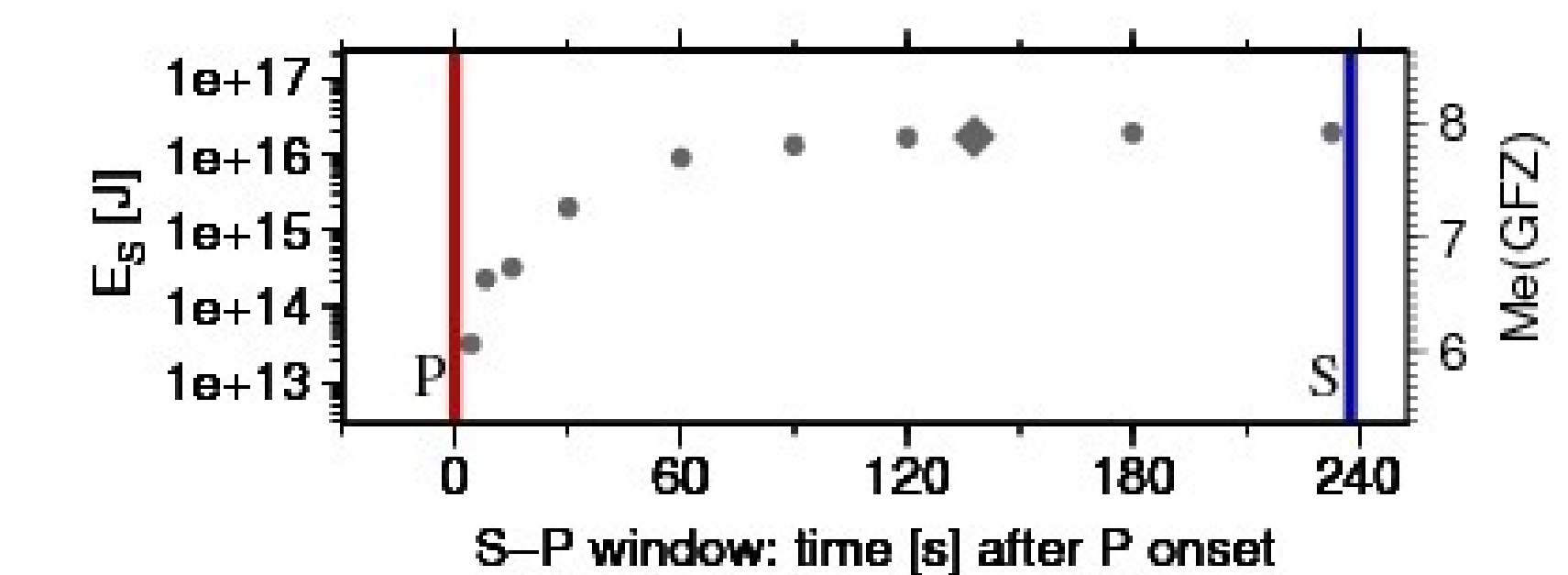
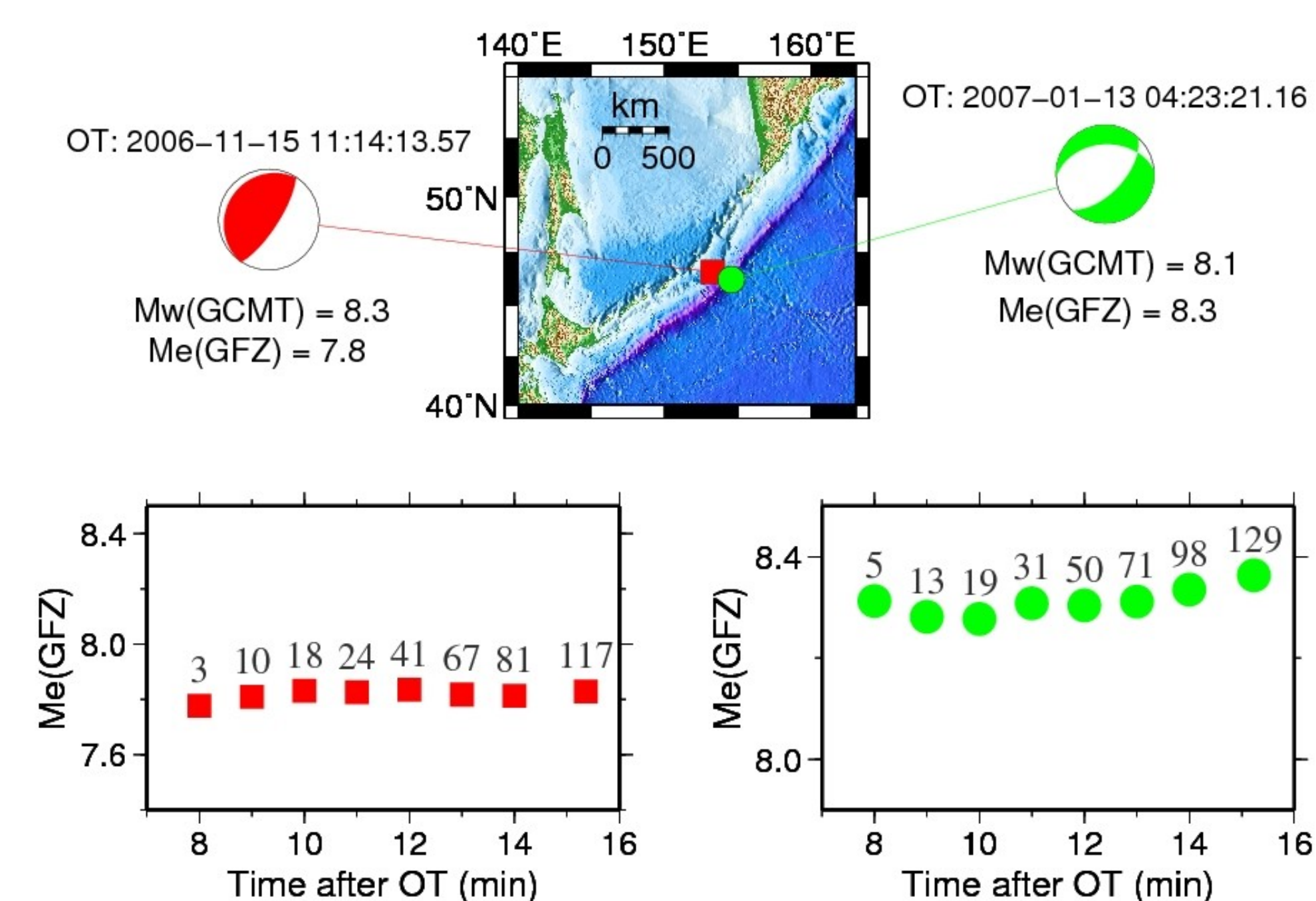
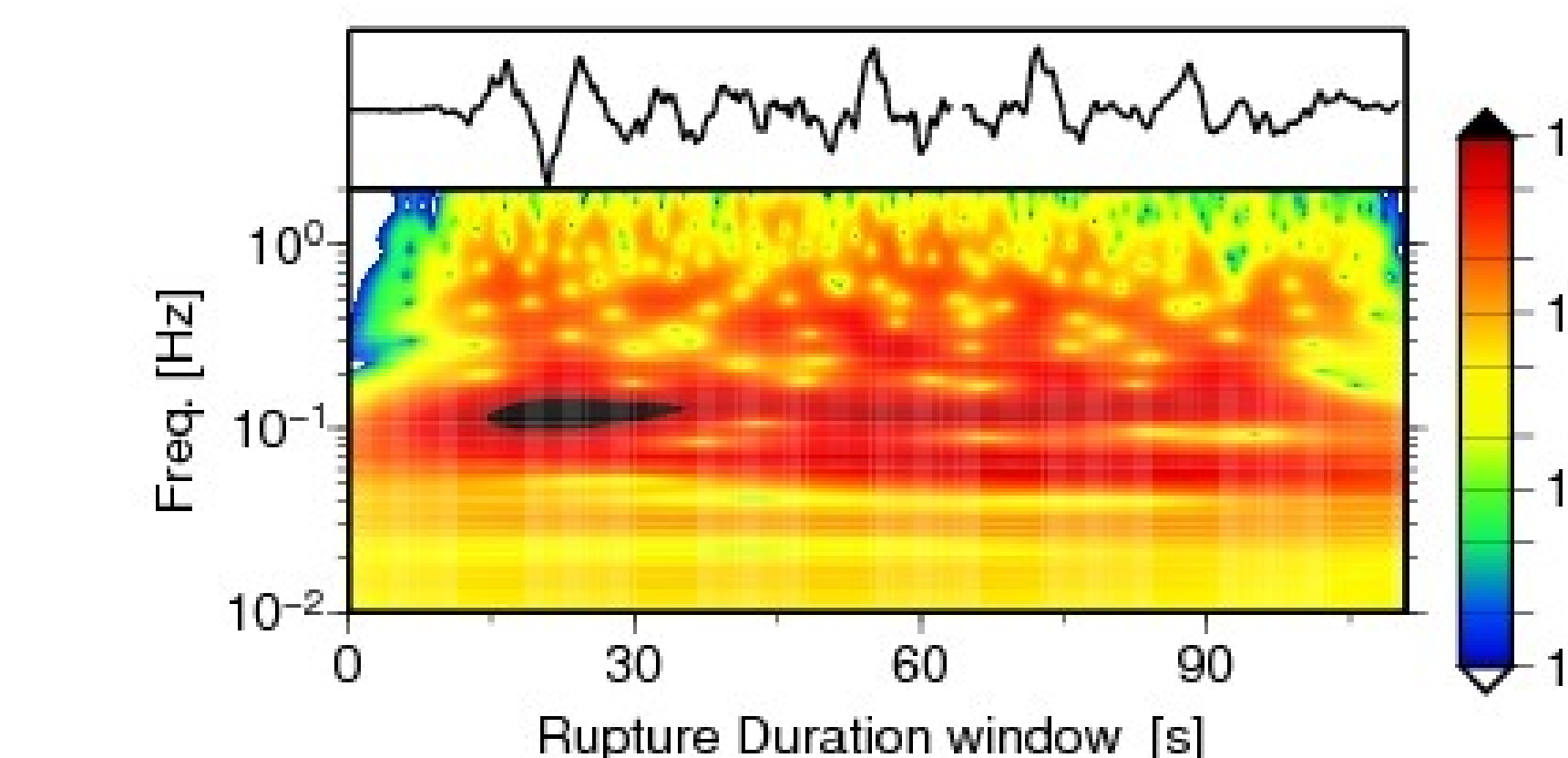
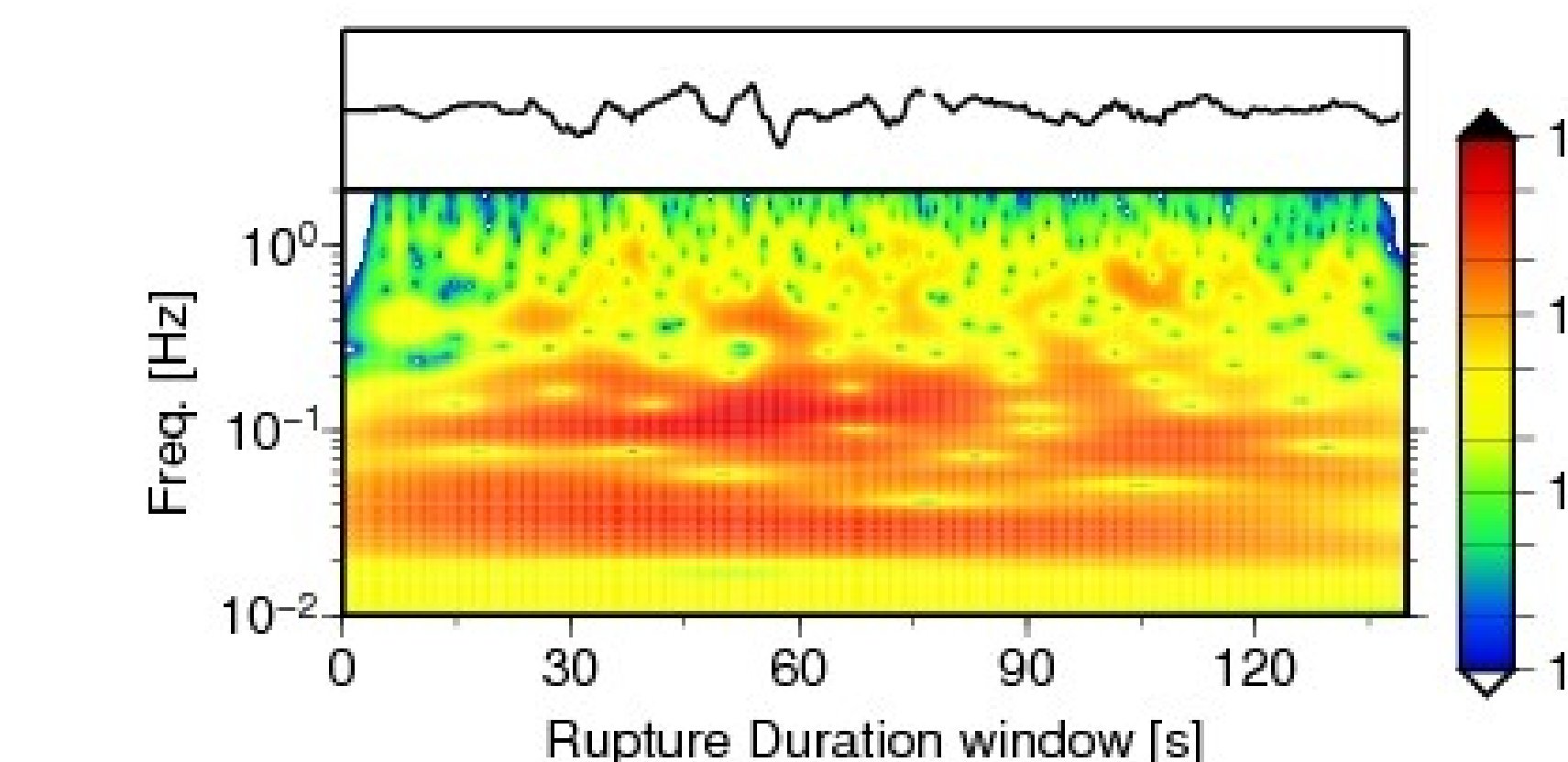
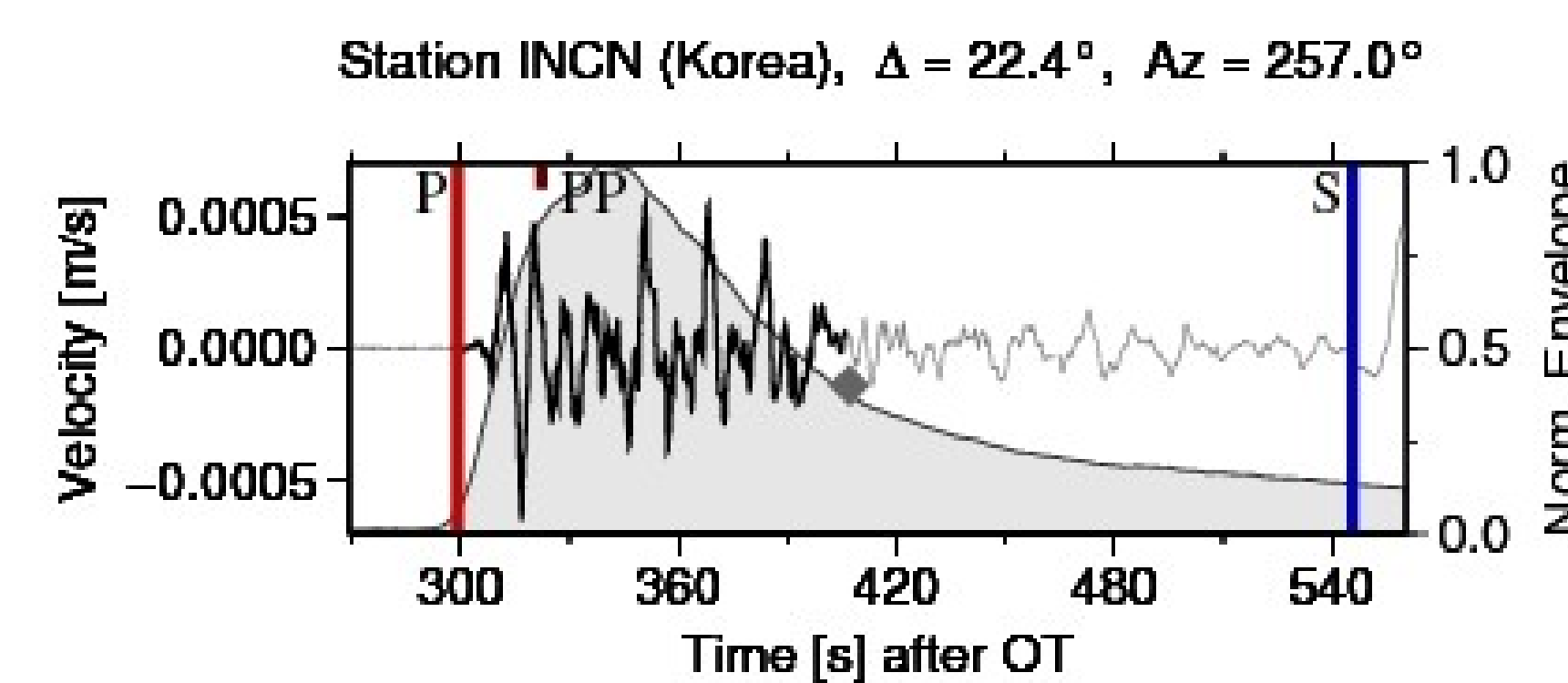
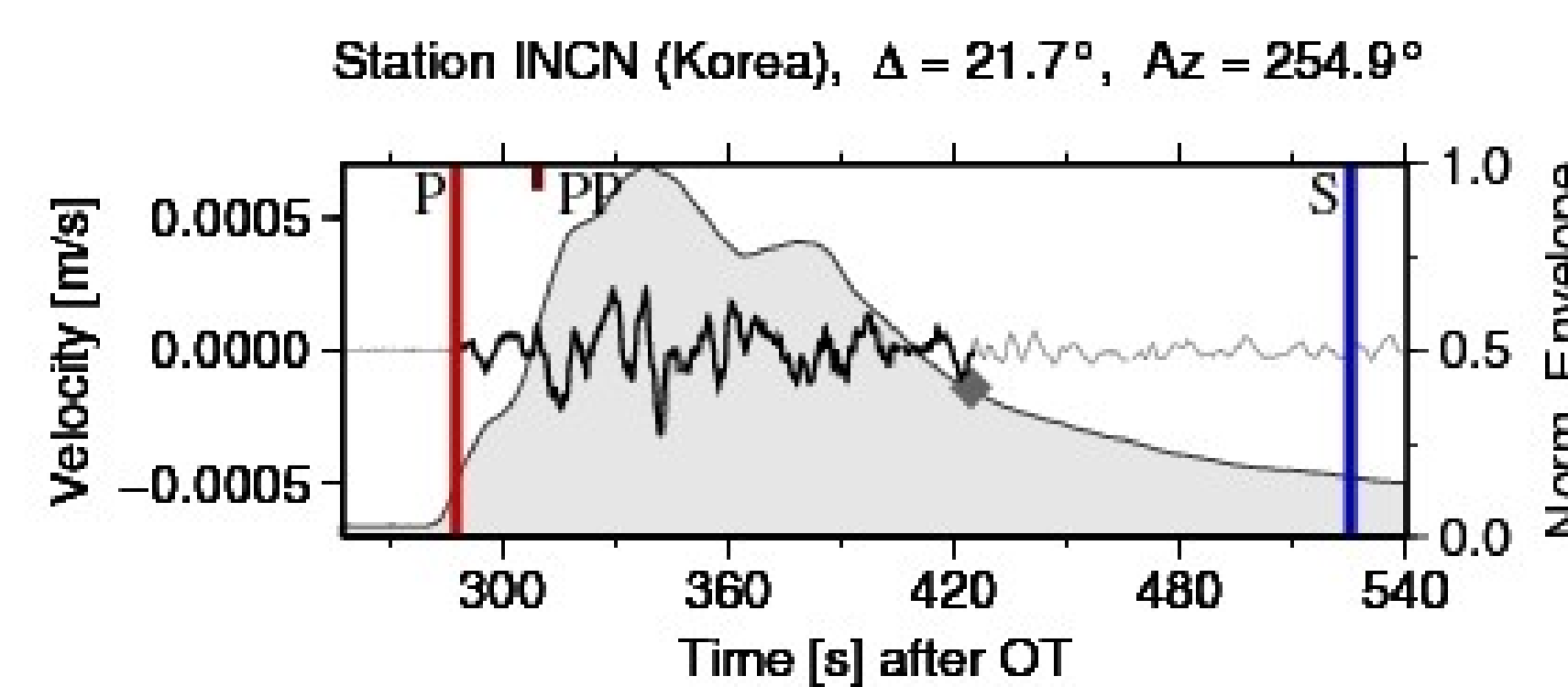
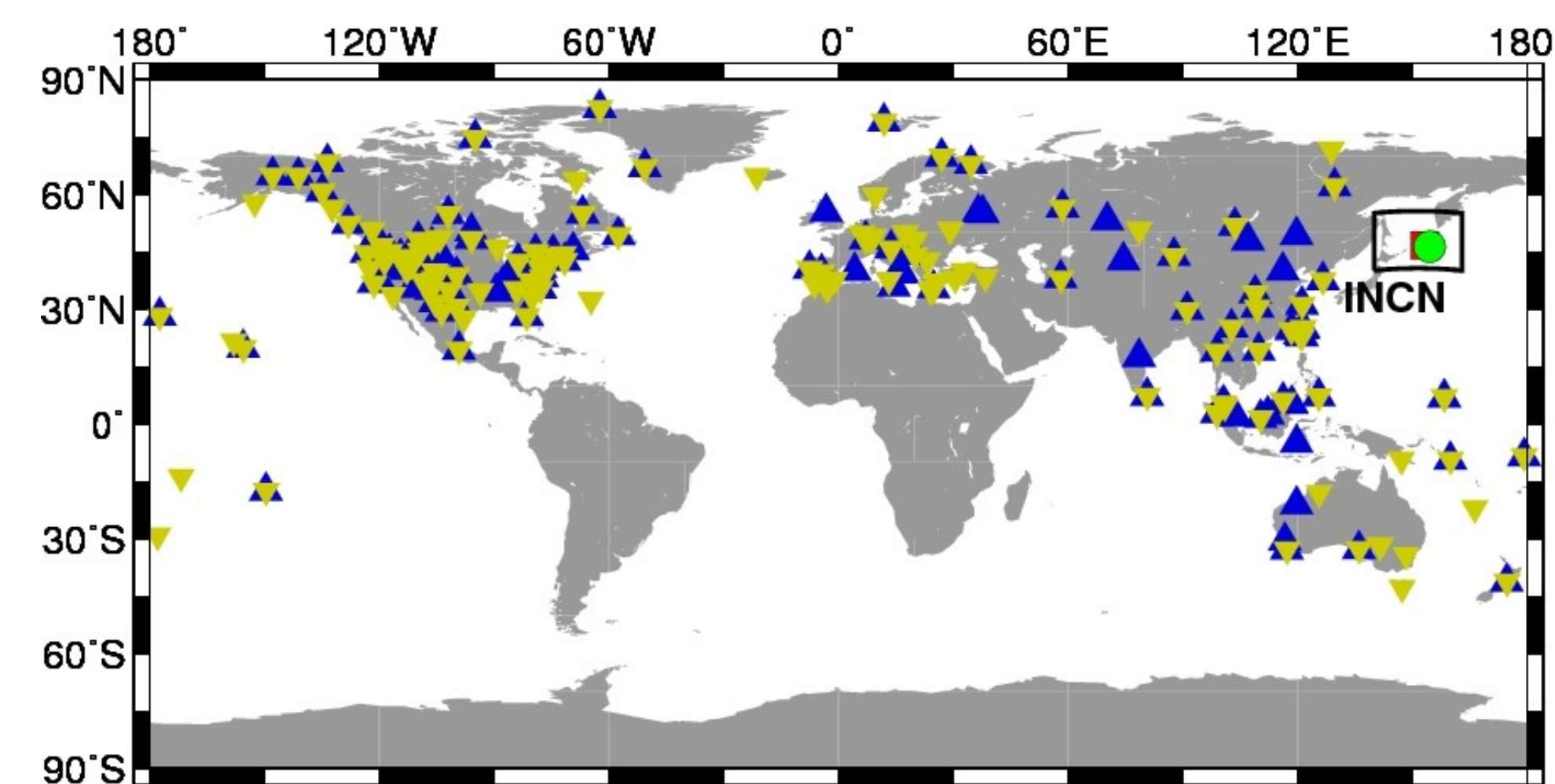
## Comparisons of the rapid $M_e(GFZ)$ with $M_w$

We analyzed 767 shallow earthquakes in the  $M_w$  range of 5.5 - 9.0, which occurred between March 1990 and December 2007. The events have been grouped according to their fault plane. The Figure on the right shows the comparison of a)  $M_w(GCMT)$  with  $M_e(GFZ)$  for 767 events, and b) of  $M_w(USGS)$  with  $M_e(GFZ)$  for 720 events. These comparisons show that  $M_w$  and  $M_e$  can be significantly different, and, therefore, they should be used jointly for better assessing the shaking and the tsunami potential of large earthquakes. In the following the importance of complementing  $M_w$  and  $M_e$  is highlighted by considering the representative cases of two great earthquakes occurred recently in the Kuril Islands and two events in the Sumatra region.



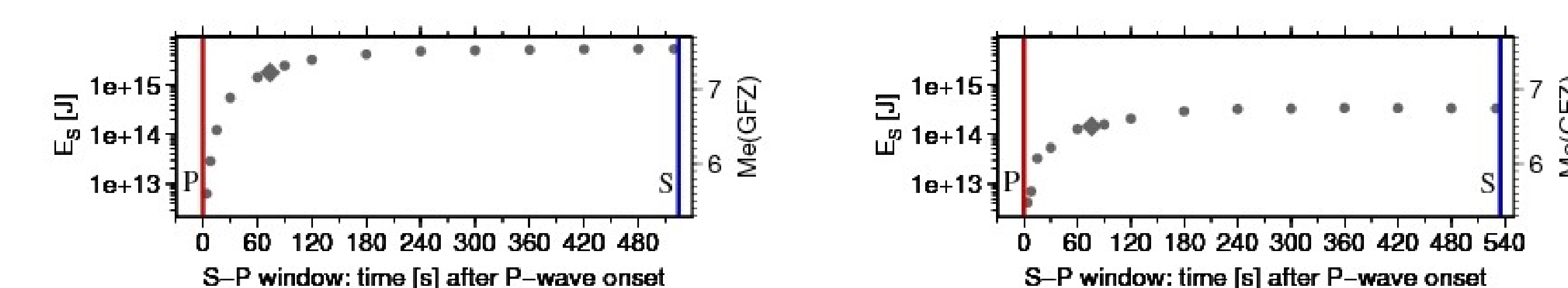
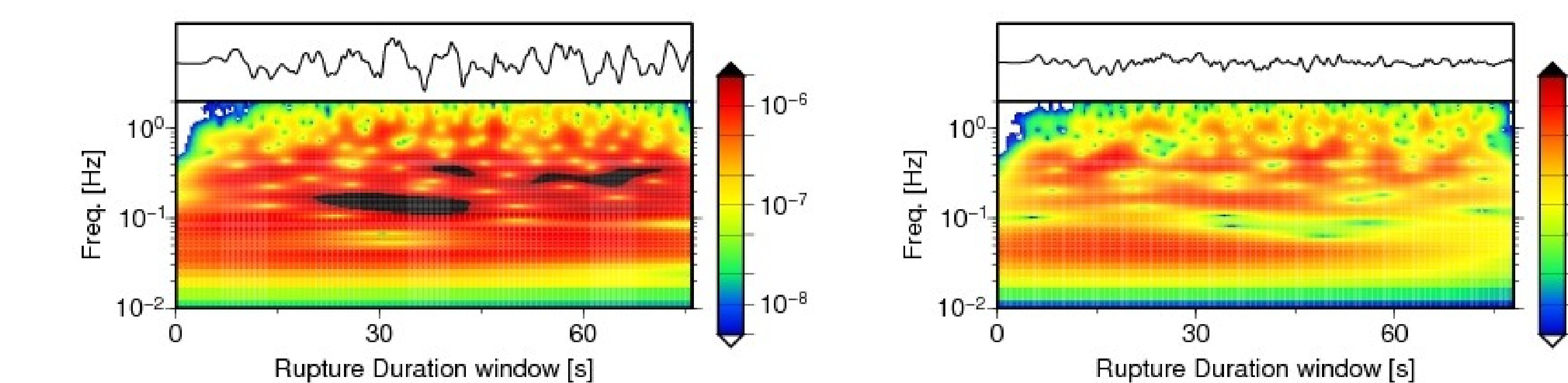
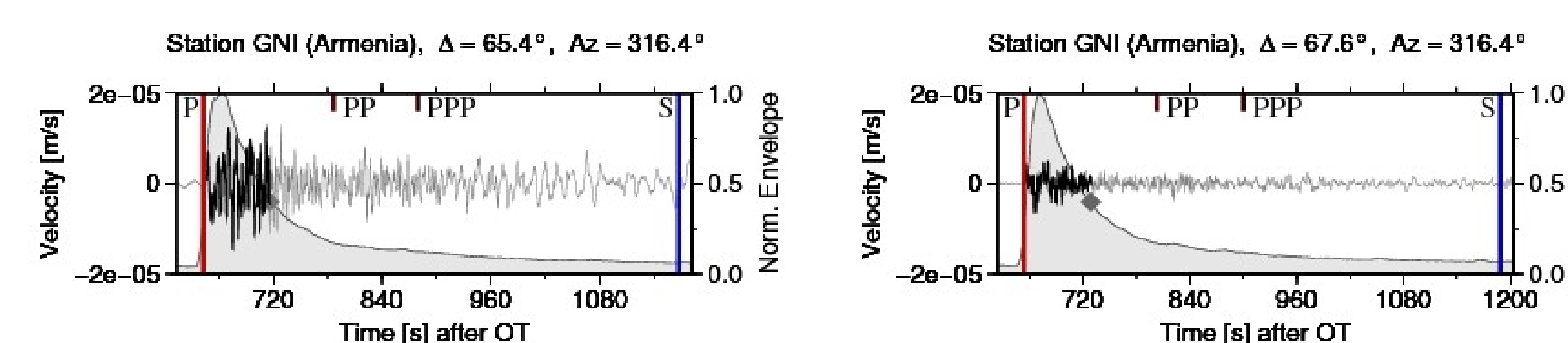
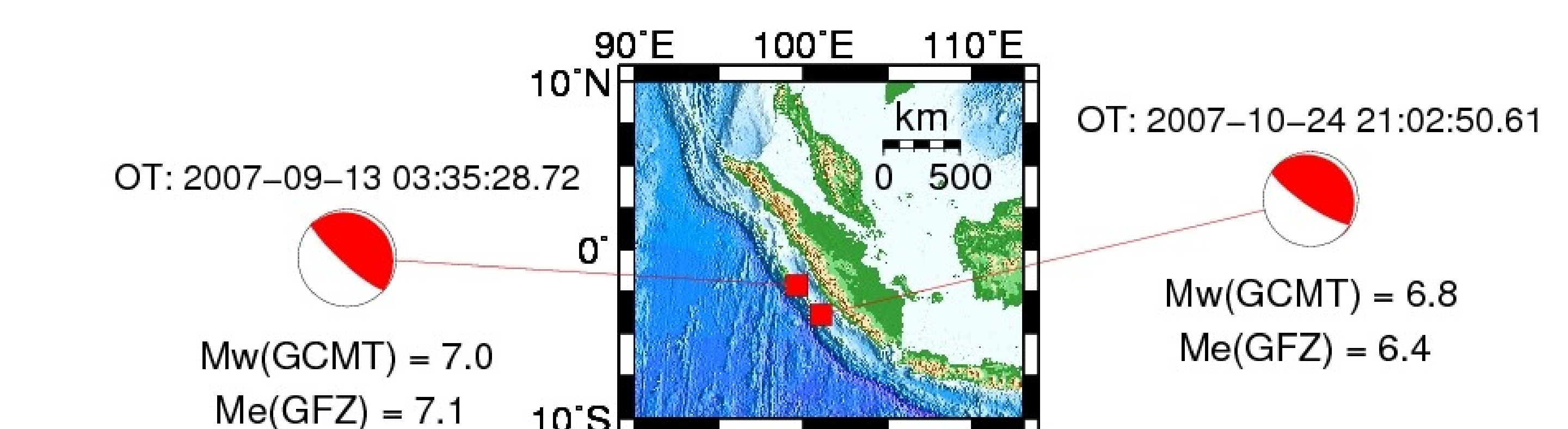
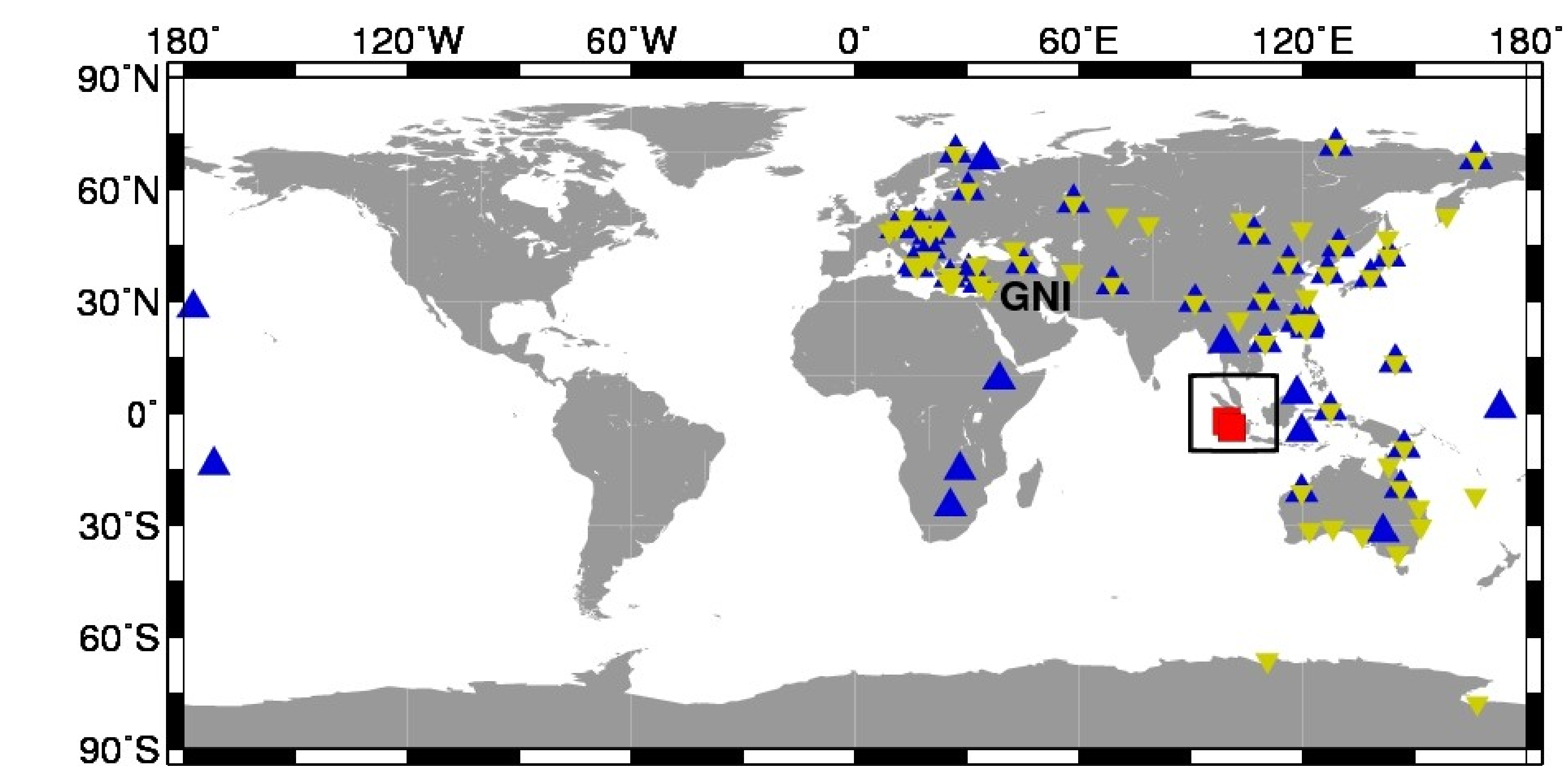
## Importance of comparing $M_w$ and $M_e$ and suitability of $M_e$ for rapid response systems: an example from two great Kuril Islands earthquakes

Map showing in blue the station locations used to compute  $M_e(GFZ)$  for the event of 15 November 2006, and in yellow the ones used for the event of 13 January 2007. The fault plane solutions from the GCMT project are also shown along with the  $M_w(GCMT)$  and the rapid  $M_e(GFZ)$ . Our preliminary (alarm)  $M_e$  could be available already about 10 minutes after OT (also for these two earthquakes occurred in a remote area). Below are shown also the results at the station INCN in Korea, where the large difference in the high-frequency spectral amplitude (highlighted by the  $S$ -transform) is explained by the difference in  $M_e$  despite the similarity in  $M_w$  for the two events.



## Importance of comparing $M_w$ and $M_e$ : an example from two Sumatra earthquakes

Map showing in blue the station locations used to compute  $M_e(GFZ)$  for the event of 13 September 2007, and in yellow the ones used for the event of 24 October 2007. The fault plane solutions from the GCMT project along with the  $M_w(GCMT)$  and the rapid  $M_e(GFZ)$  are also shown. Below, the results at the station GNI in Armenia show a large difference in the high-frequency spectral amplitude (highlighted by the  $S$ -transform). Such a difference is explained by the difference in  $M_e$  despite the similarity in  $M_w$  for the two events.



## Summary

- Spectral amplitude decay functions for different frequencies have been computed given the reference Earth model AK135Q that are used to accomplish in a rapid and robust way the correction for the wave propagation effects from the source to the receivers.
- Our procedure calculates  $E_s$ , and hence  $M_e$ , for cumulative P-wave windows up to the S-wave arrival if the rupture duration lasts several minutes, so that the problem of the time window saturation effect is avoided.
- The results for the two great Kuril Islands earthquakes show that our procedure is able to provide a stable  $M_e$  determination within 10 min after OT even for large earthquakes occurring in remote places.
- As  $M_w$  and  $M_e$  provide information about the static and dynamic properties of the source process, respectively, they should be used systematically together to better assess the earthquake’s damage potential.

## References

Di Giacomo, D., Grosser, H., Parolai, S., Bormann, P., and Wang, R. (2008). Rapid determination of  $M_e$  for strong to great shallow earthquakes. *Geophys. Res. Lett.* 35, L10308, doi:10.1029/2008GL033505.  
Wang, R. (1999). A simple orthonormalization method for stable and efficient computation of Green’s functions. *Bull. Seism. Soc. Am.*, 89(3), 733-741.

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