©2022 Published in 6th International Symposium on Natural Hazards and Disaster Management
21-23 October 2022 (ISHAD2022 Bursa - Turkey)
https://doi.org/10.33793/acperpro.XXXX

# Rapid Magnitude Determinations for Tsunami Early Warning: A sample case, October 30, 2020, Samos Island Earthquake

*1Timur TEZEL
1Department of Earth Sciences, Durham University, Durham, DH1 3LE, UK

**Abstract:**

It is vital to calculate the magnitude of an earthquake to give a response and disseminate the early warning to evacuate the people as soon as possible. Generally, the magnitude determination process takes a couple of minutes and has some difficulties because the propagation effect depends on the epicentral distances. The moment magnitude is calculated for large earthquakes, in general, using body waves that it takes at least ten minutes to calculate. This time is too much for giving an alarm and evacuating the people who live near the coastal areas. This study is concentrated improve and implementing the P-wave moment magnitude calculations to use in early warning issues by using a sample case that occurred on October 30, 2020, on Samos Island that is near to Aegean coast of Turkey. It was destructive effects on İzmir. In total, 115 people have lost their lives and more than a thousand people are wounded. The magnitude of this event was announced as 6.6 (Mw) by the Disaster and Emergency Presidency (AFAD), Earthquake Institute. A small-scale tsunami wave arrived in the Sığacık-Seferihisar region. The P-wave moment magnitude is calculated as 7.0 in this study, and it is similar to the Global Centroid Moment Tensor Solution (Mw-GCMT) result. This study shows the technique can be used for early warning purposes at regional distances.

**Keywords:** Turkey, Tsunami, Early Warning, Moment Magnitude, Rapid Response

## 1. Introduction

Turkey is situated in a very seismically active region that is comprised under movements of the African, Arabian and Eurasia plates. North Anatolian Fault Zone (NAFZ), East Anatolian Fault Zone (EAFZ) and Western Graben system in western Turkey are the main actors of seismicity in Turkey. Furthermore, The Hellenic Arc and the Cyprus Arc are the other actors to generate destructive earthquakes which have triggered tsunami potential. Figure 1 is showing a simplified tectonic picture of Turkey and around.

Reviewing the literature, we can understand that some destructive earthquakes triggered tsunamis in history and tsunami waves arrived on the southwest coasts of Turkey and their remnants were remarked with some studies [1].

*Corresponding author: Address: Department of Earth Sciences, Durham University, Durham, UK, DH1 3LE, UK.
E-mail address: timurtezel@yahoo.com

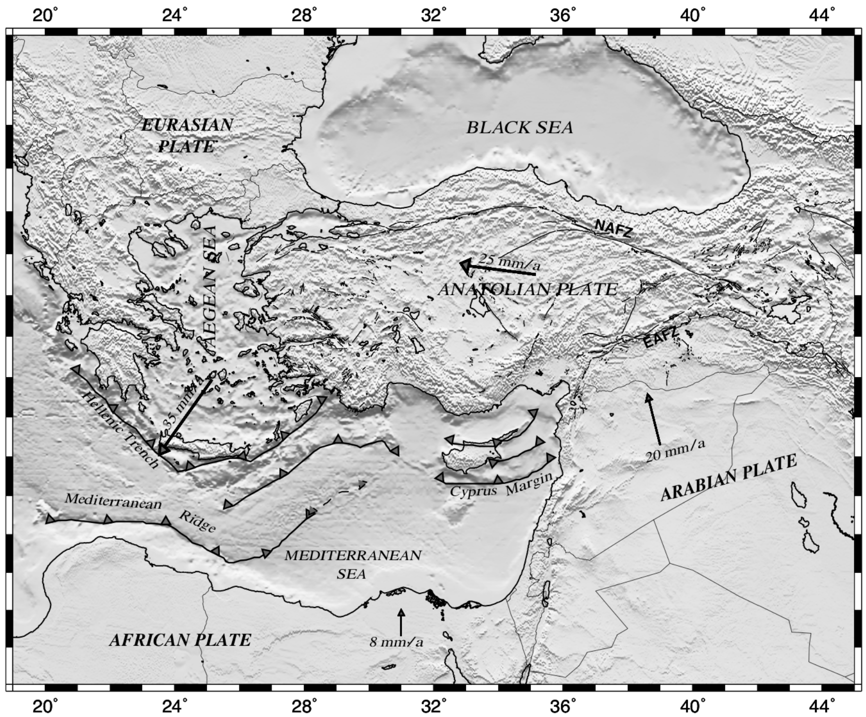


**Figure 1.** General tectonic view of Turkey and its surrounding [2]

The main point of this study is to improve a technique to calculate the magnitude of an earthquake just after some seconds to estimate its power and effects on urban areas. It is very important to give an alarm and evacuate the people beside the stopping industry such as gas, electricity and transportation to minimize the human and economic loses.

A P-wave procedure known as the Mwp-P-wave moment magnitude technique [3, 4, 5] considers very broad-band and P-wave displacement seismograms. These displacement seismograms are integrated and corrected for geometrical spreading and average radiation patterns to obtain scalar moments at each station. Many studies [6, 7, 8, 9, 10, 11] proposed different ways to compute magnitude determinations based on P-wave signals.

October 30, 2020, earthquake was selected as a sample because it had a moment magnitude of 7.0 (GCMT- Global Centroid Moment Tensor) but its magnitude was announced as 6.6 by the national seismological observatory. The national seismic network of Turkey is operated by the Disaster and Emergency Management Presidency, Ministry of Interior (AFAD), which has more than 300 broadband and about 600 strong-motion stations that would be a great chance to use together for fast magnitude calculation.

## 2. Materials and Method

In this study, the P-wave moment magnitude was calculated using different ways and compared their results. Tsuboi et al. [3] described the derivation of the broadband P-wave moment magnitude, Mwp, from the vertical component of far-field P-wave displacement. P-wave displacement was produced from both velocity seismogram and acceleration seismograms in this study and used to obtain a mean Mwp magnitude.

This technique depends on the assumption that seismic moment can be obtained from the P-wave portion of broadband vertical displacement waveforms $u_z$,

$$M_0 = \frac{4\pi\rho\alpha^3 r}{F^p} \left| max \int u_z(x_r, t)dt \right| \quad (1)$$

where ρ and α are the average density and P-wave velocity along the propagation path, respectively, r is the epicentral distance, and $F^p$ is the radiation pattern.

The seismic moment is calculated from the maximum amplitude in the selected P-wave portion. The moment magnitude is computed at each station with no correction for the radiation pattern using the standard moment magnitude formula,

$$M_w = \frac{(logM_0 - 9.1)}{1.5} \quad (2)$$

where $M_0$ is in Nm [12, 13].

In a general way, Mwp is calculated from adding 0.2 to the obtained Mw by applying Whitmore [14] correction. Also, Tsuboi et al. [3] recommended removing results that are more than one standard deviation from the mean.

In this study, neither adding 0.2 to moment magnitude nor removing values at the out of one standard deviation did not apply to obtained moment magnitudes. This study is the first at using both velocity and acceleration records to calculate the P-wave moment magnitude. The P-wave velocity was calculated using P-wave arrival time and distance for each epicentre and station pair to avoid some radiation effects on the fixed velocity value.

The main issue is the selection of the time window on seismograms to calculate the P-wave moment magnitude. Either using a fixed time window or a moving window cause some problems because it is very difficult to catch the right source duration at moment magnitude calculations [15, 16]. To overcome this type of problem, this study proposed the use of a time window that starts 10sec before P-wave arrival and finishes at S-wave onset for each seismogram. The seismograms that were clipped at near epicentral distances were removed from the calculations.

Data process steps are;

- Apply four pols Butterworth filter
- Pick P- and S- wave onsets
- Calculate P-wave velocity using P-wave onset and epicentral distance
- Cut the records using the ts-tp time window,
- Remove trend and mean from the records,
- Calculate the Mwp from velocity records by converting them to integrated displacement records.

Figure 2 shows the calculation procedure for the event recorded at the 3526-acceleration station.

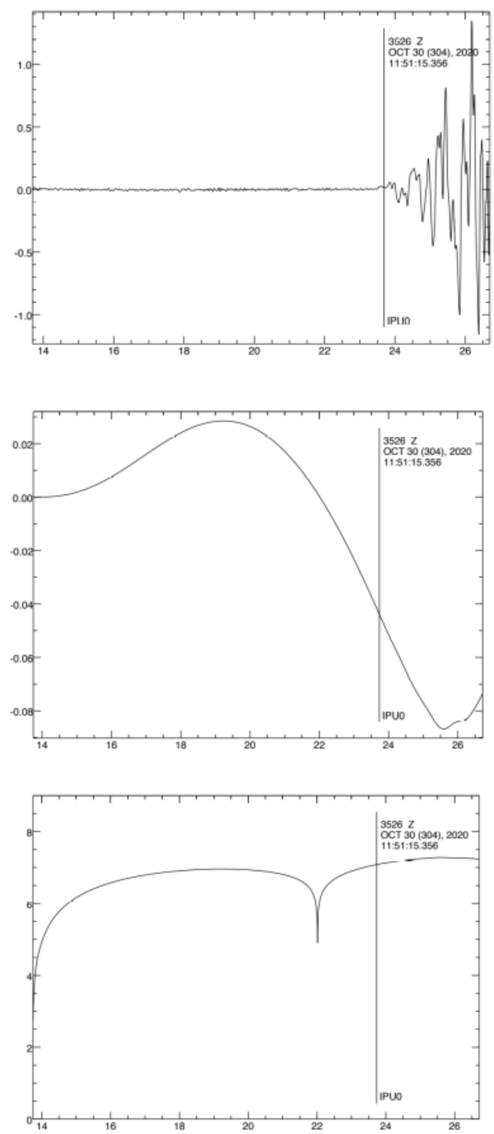


Figure 2. Mwp Calculation procedure for the 3526 seismic station using acceleration seismogram. Acceleration seismogram (top), integrated displacement (middle) and the MwpA graph (bottom).

Hypocentral parameters of the used event are listed in Table 1 with the number of stations used in each calculation and Figure 3 shows the epicentre of the event and used stations. Broadband seismic stations equipped with Guralp CMG-3T seismometers and strong motion seismic stations equipped with Guralp CMG-5T and GeoSIG type seismometers. All used seismograms were downloaded from the Bogazici University, Kandilli Observatory and Earthquake Research Institute (KOERI), and Disaster and Emergency Management Presidency, Ministry of Interiors (AFAD) databases.

**Table 1.** Focal parameters of used earthquakes with the determined moment magnitudes ($Mwp_V$ and $Mwp_A$) of the events in this study.

| **Date** | **O.T. (UTC)** | **Lat (°)** | **Lon (°)** | **Mw (GCMT)** | **Mw(AFAD)** | **N.Sta** | **$Mwp_V$** | **$Mwp_A$** |
|---|---|---|---|---|---|---|---|---|
| 2020/10/30 | 11:51:34.8 | 37.76 | 26.68 | 7.0 | 6.6 | 74 | 7.0 | 7.0 |

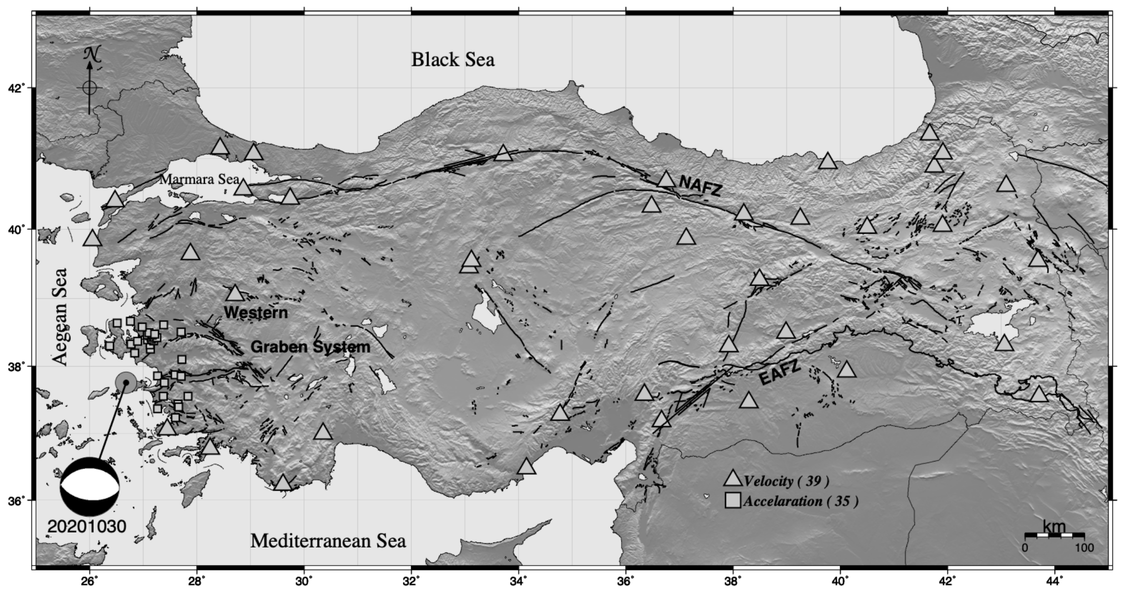


**Figure 3.** Used velocity and acceleration seismic stations and event

## 3. Results

The Samos Island earthquake occurred in the Aegean Sea with a magnitude of 7 (Mw) on October 30, 2020. It caused casualties in Izmir and a small-scale tsunami wave that reached Seferihisar as high as 1.9 m and penetrated 1.3 km in Sigacik [17].

Thirty-nine vertical velocity seismograms and thirty-five vertical acceleration seismograms were used in this study to calculate Mwp. Table 2 shows the used stations and the calculated Mwp values at each station and the mean value calculated from the arithmetic mean of all stations. The Mwp magnitude was determined as 7.0 in this study.

**Table 2.**

| Station | Distance (km) | $Mwp_V$ | Station | Distance (km) | $Mwp_A$ |
|---|---|---|---|---|---|
| BDRM | 102,57 | 6,65 | 3536 | 50,44 | 6,84 |
| TURN | 176,62 | 7,06 | 905 | 52,69 | 6,50 |
| DEMI | 227,83 | 6,55 | 911 | 62,64 | 7,10 |
| BALB | 233,34 | 6,96 | 3523 | 63,57 | 7,01 |
| BOZC | 237,43 | 7,19 | 920 | 65,19 | 5,99 |
| GELI | 293,40 | 7,20 | 3528 | 66,13 | 6,52 |
| AKAS | 310,67 | 6,61 | 918 | 67,39 | 6,74 |
| KORT | 335,79 | 6,71 | 3533 | 67,89 | 7,36 |
| ARMT | 364,52 | 6,80 | 3516 | 70,25 | 6,93 |
| ADVT | 397,53 | 6,95 | 3538 | 73,22 | 7,38 |
| ELBA | 405,07 | 7,01 | 3506 | 78,76 | 6,81 |
| ISK | 420,29 | 6,73 | 921 | 81,32 | 7,21 |
| AFSR | 587,17 | 6,77 | 3517 | 81,86 | 7,20 |
| BBAL | 594,58 | 6,77 | 3512 | 82,30 | 7,28 |
| KIZK | 678,14 | 6,44 | 3518 | 84,87 | 7,48 |
| ILGA | 707,39 | 6,88 | 3519 | 85,66 | 7,47 |
| GULE | 717,45 | 7,33 | 3521 | 85,92 | 6,76 |
| ANDN | 852,58 | 7,13 | 3522 | 87,72 | 6,99 |
| KAMA | 885,36 | 6,83 | 3513 | 88,51 | 6,94 |
| TOKA | 894,16 | 7,14 | 3511 | 89,13 | 7,32 |
| ERBA | 927,82 | 7,32 | 3514 | 89,88 | 7,41 |
| SCER | 936,41 | 7,08 | 3524 | 89,97 | 7,16 |
| AKCD | 988,26 | 6,99 | 922 | 91,14 | 7,52 |
| ATAB | 1025,33 | 6,81 | 4823 | 92,16 | 6,55 |
| SUSE | 1033,86 | 7,05 | 3520 | 92,31 | 7,21 |
| KEMA | 1043,04 | 6,51 | 4822 | 92,33 | 6,57 |
| ELZG | 1081,13 | 6,87 | 3526 | 94,53 | 7,02 |
| KELT | 1120,80 | 7,28 | 4814 | 95,12 | 6,62 |
| MACK | 1180,88 | 6,63 | 3527 | 98,66 | 6,92 |
| DIYA | 1182,19 | 7,23 | 3539 | 99,10 | 7,10 |
| KOPT | 1223,38 | 7,15 | 4817 | 99,96 | 6,43 |
| DDEM | 1343,31 | 7,02 | 3534 | 100,40 | 6,44 |
| HOMI | 1343,12 | 7,25 | 919 | 104,36 | 7,07 |

| | | | | | |
|---|---|---|---|---|---|
| DBOC | 1346,15 | 6,88 | 4501 | 112,84 | 7,19 |
| DAGI | 1360,56 | 7,25 | 4507 | 122,38 | 7,12 |
| GEVA | 1437,30 | 7,28 | | | |
| KARS | 1450,77 | 7,26 | **Mean $Mwp_A$** | | 7,0 |
| DYDN | 1491,51 | 6,89 | | | |
| HAKT | 1500,53 | 6,89 | | | |
| **Mean $Mwp_V$** | | 7,0 | | | |

## 4. Discussion

This study helps to understand of importance using of both velocity and acceleration seismograms to calculate a reliable and fast moment magnitude from P-wave. If the seismic networks have both instruments, it will be an advantage for each other. Mostly, weak motion seismograms clip at seismic stations that are located around epicentre, although strong motion seismograms can be used at these short distances to cover a wide azimuthal coverage (Figure 4) The research showed how difficult it to select a fixed time window to use in magnitude calculation and proposed a time window that is between P-wave and S-wave onsets for velocity seismograms whereas only three seconds are enough to give a reliable magnitude value on acceleration seismograms. The main task is in this study to show a way to calculate a moment magnitude in a short time as possible and proved our results.

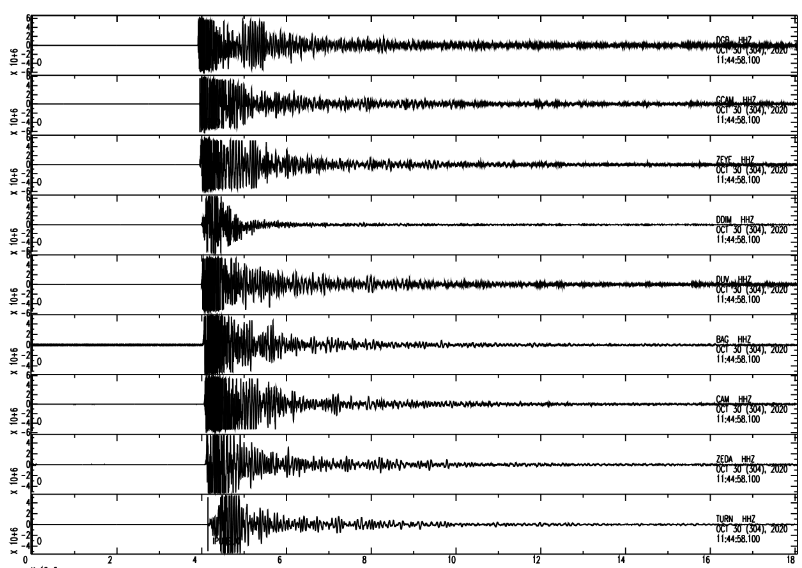

**Figure 4.** Clipped seismograms

## Conclusions

P-wave moment magnitude determination technique has been adapted using velocity and acceleration records for early warning purposes and rapid response action by the authorities. The magnitude can be calculated ±0.1-unit difference with GCMT within a couple of minutes by velocity seismograms and in some tens of seconds by acceleration seismograms. The research strongly proposed to the seismological observatories to use both velocity and acceleration seismograms to determine the P-wave moment magnitude in a short time.

## Acknowledgements

Thanks to KOERI and AFAD for seismic data, we used GMT (Generic Mapping Tools) by Wessel and Smith [18] to generate the figures.

## References

[1] Fokaefs A, Papadopoulos G. Historical earthquakes and tsunami sources in Eastern Mediterranean Sea. Geophys Res Abs 2005; 7:00732.
[2] Tezel T, Shibutani T, Kaypak B. Crustal thickness of Turkey determined by receiver function. J Asian Earth Sci 2013; 75:36–45
[3] Tsuboi S, Abe K, Takano K, Yamanaka Y. Rapid determination of Mw from broadband P waveforms. Bul Seismol Soc Am 1995; 83:606–613.
[4] Tsuboi S, Whitmore PM, Sokolowski TJ. Application of Mwp to deep and teleseismic earthquakes. Bul Seismol Soc Am 1999; 89:1345–1351.
[5] Tsuboi S. Application of *Mwp* to tsunami earthquake. Geophys Res Lett. 2000; 27:3105–3108.
[6] Menke W, Levin V. A strategy to rapidly determine the magnitude of great earthquakes. Eos Trans Am Geophys Un 2005; 86(19):185. https://doi.org/10.1029/2005EO190002
[7] Lockwood OG, Kanamori H. Wavelet analysis of the seismograms of the 2004 Sumatra-Andaman earthquake and its application to tsunami early warning. Geochem Geophys Geosyst 2006; 7:Q09013. https://doi.org/10.1029/2006GC001272
[8] Lomax A. Rapid estimation of rupture extent for large earthquakes: application to 2004, M9 Sumatra-Andaman mega-thrust. Geophys Res Lett 2005; 32:L10314. https://doi.org/10.1029/2005GL022437
[9] Lomax A, Michelini A. Rapid determination of earth- quake size for Hazard warning. Eos Trans Am Geophys Un 2005; 86(21):202.
[10] Lomax A, Michelini A. $M_{wpd}$ : a duration-amplitude procedure for rapid determination of earthquake magnitude and tsunamigenic potential from P waveforms. Geophys J Int 2009; 176:200–214. https://doi.org/10.1111/j.1365-246X. 2008.03974.x
[11]Lomax A, Michelini A, Piatanesi A. An energy-duration procedure for rapid determination of earthquake magni- tude and tsunamigenic potential. Geophys J Int 2007; 170:1195– 1209. https://doi.org/10.1111/j.1365-246X.2007.03469.x
[12] Kanamori H. The energy release in great earthquakes. J Geophys Res 1977; 82:2981–2987.

[13] Hanks T, Kanamori H. A moment magnitude scale. J Geophys Res 1979; 84:2348–2350.
[14] Whitmore PM, Tsuboi S, Hirshorn B, Sokolowski TJ. Magnitude dependent correction for Mwp. Sci Tsunami Hazards 2002; 20:187–192.
[15] Tezel T, Yanik K. Improvement in Mwp magnitude determinations and applications to earthquakes in Turkey. Seismol Res Let 2013; 84:91–96.
[16] Tezel T. Application of P-wave magnitude to earthquakes for tsunami early warning in and around South- Western Turkey. Studio Geophys Geod 2015; 59.https://doi.org/ 10.1007/s11200-014-0825-2
[17] Dağ B. "Turkey sees larger tsunami after latest quake". Anadolu Agency 2020. https://www.aa.com.tr/en/turkey/tur- key-sees-larger-tsunami-after-latest-quake/2031162t (Last accessed: 27/11/2020).
[18] Wessel P, Smith WHF. New, improved version of Generic MappingTools released. EOS Trans AGU 1998; 79:579.