DETERMINATION OF SOME COMMON MAGNITUDE SCALES USING BROADBAND DIGITAL SEISMOGRAMS

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ABSTRACT

Pakistan Meteorological Department (PMD) has started establishing the new digital seismic network including broadband stations in Pakistan after the 2005 Kashmir earthquake. This study was aimed to summarize the basic information to make a strategy for an appropriate way of the routinary tasks of the new seismic network. In this paper, we have checked some magnitude scales commonly used with broadband seismograms today and their operability. For this purpose, we have analyzed the 2005 Kashmir earthquake taking data from seventeen broadband stations through IRIS to determine the moment magnitude in the time domain using few sets of density and P-wave velocity as well as in the frequency one. As a whole we have made a comparison between the various magnitude scales like Mw, Mwp, Ms(BB) and Ms20. In conclusion, we emphasize on Mw determination and its application in future for the PMD new network which will be a first step towards the disaster mitigation based on the quick and rapid determination.

Keywords: Broadband, Seismic Moment, Seismograms, Frequency domain, Time domain

INTRODUCTION

After the 2005, Kashmir earthquake, Pakistan Meteorological Department (PMD) obtained a set of new digital seismometers to monitor the on going seismic activities in and around Pakistan. However, the observational job on the modern seismic equipments has not been established well. The seismic staff of PMD was familiar with the old analog network, but the operation of the new digital seismic network and its handling were a challenge. Therefore, the objective of this paper is to support and overcome the problems of determination of different kinds of magnitudes and other parameters, and to bring PMD to the position to join the modern seismological society. Therefore in this paper we are going to through light on the way of determination of magnitudes.

NEW DIGITAL SEISMIC NETWORK OF PAKISTAN

After the 2005 Kashmir earthquake, PMD has started upgrading the seismic network by installing some new set of digital seismometers and accelerometers for fast calculations of the seismic activities Figure 1

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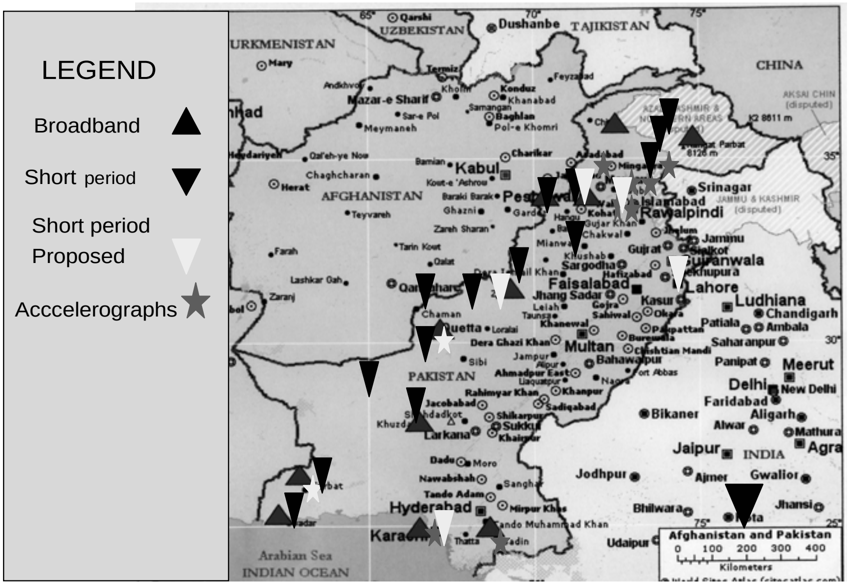


Figure 1 Planned Seismic network of PMD (analog+digital) mapped on a political map downloaded from http://geography.about.com/library/cia/blcpakistan.htm

EXPECTATIONS FOR THE NEWLY INSTALLED DIGITAL SEISMIC ETWORK

The newly established digital system will have a good impact on the output of the PMD seismological data. The newly installed broader band system will be more powerful according to its bigger number and response and it will cover the complete seismic spectrum from very low frequency to high. The collected data can be easily handled for research purposes and can be stored for long duration.

EXAMPLES OF ANALYSIS

DATA

In this paper, 2005 Kashmir earthquake was used for analysis which was obtained from the Data Management Center of Incorporated Research Institutions for Seismology (IRIS) network.

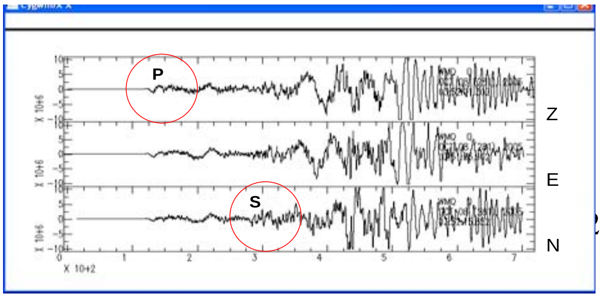
Determination of Mwp in the time domain

We used sac2000 software for analysis (http://www.llnl.gov/sac/). At first the raw waveform data was converted to velocity seismograms (Figure 2 and Figure 3).

We analyzed, the event using Tsuboi *et al* (1995), Kanjo *et al* (2006) and by using the Preliminary Reference Earth Model (PREM) (e. g., Bormann 2002) and the Mwp was obtained as shown in the Figure 5 and the result was compared with (USGS). The mathematical equation for moment is given by Tsuboi (1995) as

$$Mo' = \max\left|\int u_z(r,t)\,dt\right| \cdot 4\pi\rho\alpha^3 r \tag{1}$$

Where u_z is a vertical component of ground displacement
The values for the constants the density (ρ) and P-Wave velocity (α) are given in Table 1



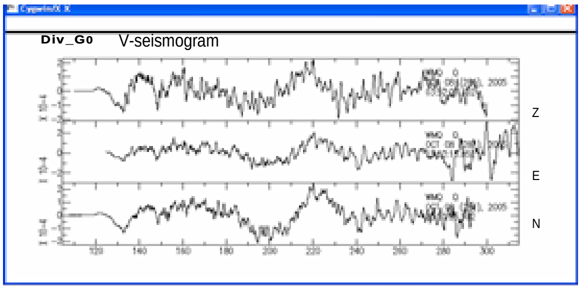


Figure 2 Raw wave form data from WMQ from WMQ Broadband station

Figure 3 Velocity seismogram (m/sec) from WMQ broadband station

From the P-wave train we removed the mean and the trend. After applying the integration twice, we got the absolute value and further by multiplying with $4\pi\rho\alpha^3 r$, where ρ density, α P-wave velocity and r hypocentral distance, the seismic moment was obtained using Eq 1 as shown in Figure 4. The peak gave Mo = 2.5×10^{20} N-m. (Mwp=7.6, Figure 5). Average values of magnitudes are given in Table 1.

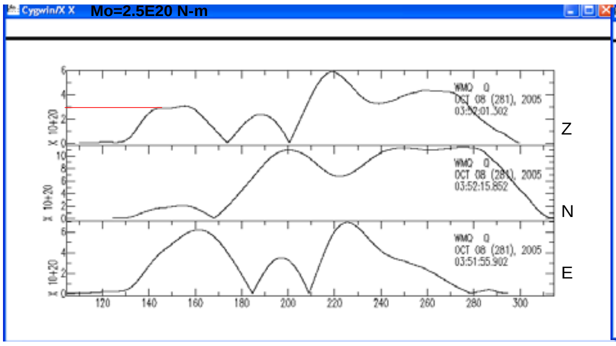


Figure 4 Mo obtained from the doubly integrated P-wave

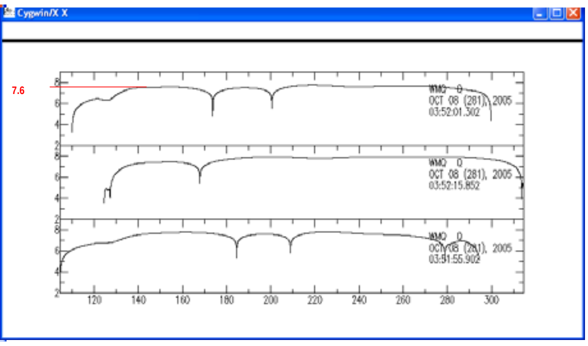


Figure 5 Integrated displacements (m-sec) from WMQ showing magnitude (Mwp 7.6)

Determination of Mw in Frequency Domain

We analyzed the same event and same seventeen seismic stations except ENH using the Fast Fourier Transform (FFT;Sac2000) from the P-wave train from vertical component and we found the value of seismic moment M_o (Mo=3×10^{20} N-m) from low frequency asymptote, as shown in Figure 6. Using the famous Eq (2) of Keilis-Borok (1960) for moment determination.

$$Mo=4\pi\rho\alpha^3 r\Omega_o/R_{\theta\phi} \tag{2}$$

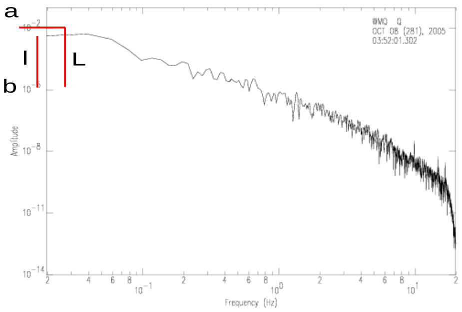


Figure 6 Fourier spectra of the P-Wave from WMQ station

An then using the famous Eq.(3) of Kanamori (1977) we found the Mw

$$Mw = 2/3\ (\log_{10} Mo - 9.1) \tag{3}$$

We got average Mw= 7.3.

Results for the moment magnitude

Figure 7 shows the variation of Mwp and Mw determined by the four cases that are summarized in Table 1. The right most column shows the determined values that are the means over the. Only in the case 4 it was determined in the frequency domain with the material properties used by Hanks and Wyss (1972).In comparison with Mw determined by USGS, the case 2 and 3 gave the best estimate, the case 1 gave slightly smaller ones but with trivial difference. The case 4 gave significantly smaller value due to the small value of ρ and α.

Table 1 input parameters for analysis

S.No	ρ(Kg/m3)	α(Km/sec)	Refeference for ρ and α	Method	Magnitude
Case 1	3400	7.9	Tsuboi et al.(1995)	Mwp in the time domain	Mwp 7.5
Case 1'	3400	7.9	Tsuboi et al.(1995)	Mw in the frequency domain	Mw 7.6
Case 2	3880	8.11	PREM model	Mwp in the time domain	Mwp 7.6
Case 2'	3880	8.11	PREM model	Mw in the frequency domain	Mw 7.7
Case 3	3400	0.16Δ+7.9	Kanjo et al.(2006)	Mwp in the time domain	Mwp 7.6
Case 4	2700	6	Hanks and Wyss(1972)	Mw in the frequency domain	Mw 7.3

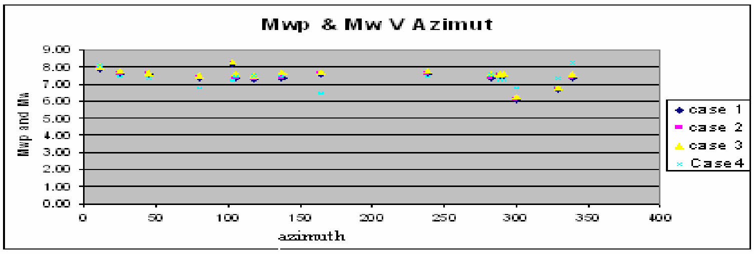


Figure 7 Mwp and Mw obtained for 16 stations

Determination of Surface Wave Magnitude Ms (BB) from Broadband Instrument

We determined Ms (BB) in the time domain using SAC2000 from broadband velocity seismograms. Picking the largest peak from the surface-wave train, we found the V_{max} (μm/sec) Figure 8. This was converted to Ms(BB) using Eq 4 (Working Group; IASPEI) given as follow

$$Ms\ (BB) = \log_{10} (Vmax/2\pi) + 1.66\log_{10} \Delta + 3.3 \qquad (4)$$

Where (A/T) max = V max/2π), where v max = ground velocity in μm/ sec. The average value for Ms(BB) was 7.4, while M_w determined by USGS was 7.6.

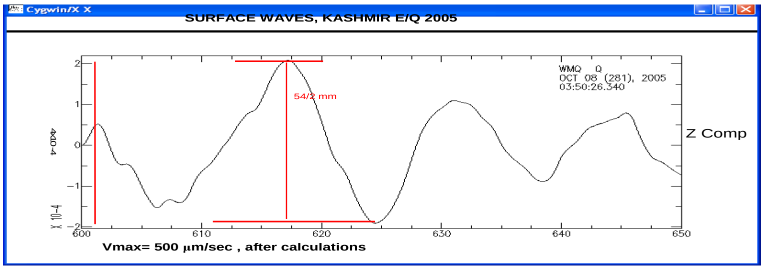


Figure8 Peak amplitude of surface wave train

Determination of mB Intermediate Period / Broadband Body Wave Magnitude

We determined mB in the time domain using SAC2000 from broadband velocity seismograms. We found the V_{max} (µm/sec), Figures 9. This value was converted to mB using Eq 5 (WG ISPAEI)

$$mB = \log_{10} (A/T)_{max} + Q (h, \Delta) \qquad (5)$$

Where $(A/T)_{max}$ can be replaced with $(V_{max}/2\pi)$, V_{max} is ground velocity in µm/s. The average value was determined 6.9 and Figure 10 shows the scattering of Ms(BB) and mB over the azimuth.

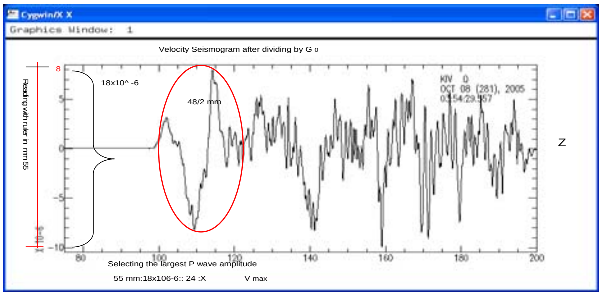


Figure 9, max amplitude from body wave, KIV station (IRIS)

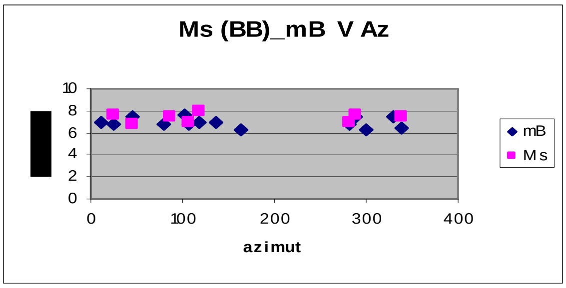


Figure 10 Ms (BB) and mB against Azimuth

DISCUSSIONS AND CONCLUSION

The information of the conventional teleseismic magnitude scales mb, Ms(20) and their broadband version mB and Ms(BB) is mainly for the global observation, e. g., international vigilance of nuclear test ban, whereas the rapid moment magnitude Mwp is used for tsunami warning due to distant great earthquake. For the latter the quickness is necessary but not so severely as local damaging earthquake. The only demand is to be observed by a broadband seismograph and this will be fulfilled after establishment of new network. Considering on the simplicity of processing mB and Ms(BB) may have advantage, whereas mb and Ms(20) are more famous although they need the instrumental correction (Table 2).

Table 2 Comparison among the common magnitude scales. * A way of correction was proposed by Whitmore et al. (2002).

Magnitude type	Domain	Seismometer type	Distance Range	Phase used	Processing required	Remarks
Mw	freq.	BB	No Limit	P	FFT	
Mwp	time	BB	No Limit	P	Integration	Saturate*
mB	time	BB	21<Δ<100	P	No need	Saturate
Ms(BB)	time	BB	2<Δ<160	Surface wave	No need	Saturate
mb	time	WWSSN_SP	21<Δ<100	P	Inst. Corr.	Saturate
Ms(20)	time	WWSSN_LP	20<Δ<100	Surface wave	Inst. Corr.	Saturate
Ml	time	WA	0<Δ<100	Body wave	Inst. Corr.	Saturate
Md	time	Not Specified	Local Event	Duration	Easy	

In general, it is better to use Mwp for tsunami warning rather than mb, mB, Ms(20) or Ms(BB) that are currently not used, because Mwp corrected may not saturate for great earthquakes (Whitmore et al. 2002). Moreover, in seismological context Mw relates directly to the seismic moment Mo that is the physical quantity of earthquake size and Mwp is a way to estimate Mw rapidly. The difference of Mw and Mwp exists only in the way of calculation; the former is done in the frequency domain and the latter in the time domain.

Consequently, all the above discussions prove that advantages of moment magnitude and other seismic parameters from the digital seismic records will improve not only the quality of seismic data but also will help in the rapid and reliable information regarding earthquake hazards and its mitigation.

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