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Full Length Research Paper

Duration magnitude calibration of Kuwait national seismic network

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One type of magnitude formula is preliminarily developed from Kuwait National Seismic Network (KNSN) data which is intended for application by the network in its seismic monitoring activities. This is the duration magnitude scale of measurement which is empirically determined and expressed as: M_D = 2.66 *log* (τ) + 0.036Δ - 1.97 + *Ci*. The magnitude formula is the result from applying multiple regression techniques to the data which have the seismic signal duration, τ, that are obtained from 6 stations of the network. To ensure applicability of the magnitude equation for the network, stations corrections were determined which is indicated the Ci for the station. The station corrections are evaluated from the average of the difference values between the proposed magnitude formulas to respective magnitude equations was obtained from each seismic station.

Key words: Duration magnitude; Kuwait National Seismic Network; Seismic signal duration.

INTRODUCTION

Magnitude is a measure of an earthquake size. This parameter is related to the released seismic energy in an earthquake and therefore important for the evaluation of earthquake hazards. A reliable and standardized measure of the size of an earthquake is essential for seismic disaster mitigation and minimization of earthquake losses. Hence, it becomes imperative for a seismic network to develop its own formulas and methods in determining and defining the seismic parameters of local earthquake events related to the level of destructiveness. It is desirable that a seismic network can promptly provides information regarding the occurrence of an earthquake of concern independently from other seismological agencies.

In 1958, Bisztricsany found a linear relation between magnitude of teleseismic events and the logarithm of the surface-wave trace duration. This concept was applied to local earthquakes with the seismic signal trace duration defined as the total length of the trace instead of the surface-wave (Solov'ev, 1965; Tsumura, 1967; Crosson, 1972; Lee et al., 1972; Real and Teng, 1973; Bakun and Lindh, 1977). Al-Arifi and Al-Aumidan (2011) conducted a local magnitude (ML) for the Kuwait national seismic network which is empirically determined and expressed as:

$$ML = \log(A) + 1.43\log(\Delta) + 1.0 + Di$$

Regional and local heterogeneity requires that each local seismic network should fundamentally develop their own methods and formulas for classifying and defining seismic events within their area of responsibility of concern.

The empirical magnitude formulas that are developed from regional and local considerations are more based on data that reflect the regional and local characteristics of geometric spreading and an elastic absorption. Hence, it is for this purpose that an attempt to develop preliminary magnitude formula from the Kuwait National Seismic Network (KNSN) stations data is undertaken, for determination of the strength of recorded local and regional seismic events. This study may also encompass the intention of promoting and cultivating regional cooperation among neighboring seismological networks.

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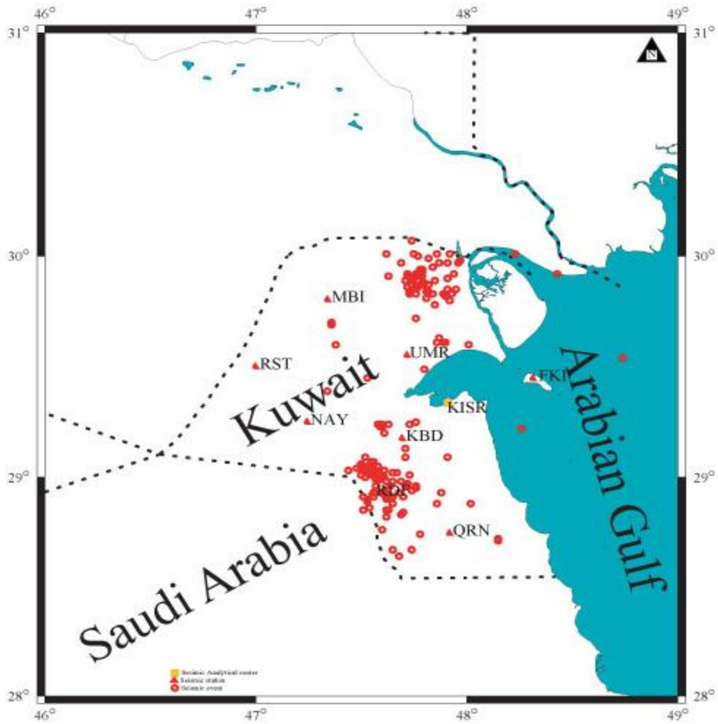


Figure 1. Location map of the Kuwait National Seismic Network stations and the analytical center.

MATERIALS AND METHODS

Data source

There are two main sources of seismic data that are referred in this study of magnitude formula development. These are the seismic bulletins from the KNSN in the period from 1998 to 2003 and the preliminary determination of epicenters (PDE) of the United States Geological Survey (USGS) corresponding to these years. The seismic data that were taken from KNSN earthquake bulletins are the duration values from its short period seismic stations: QRN, RDF, NAY, RST, MIB, and UMR. The location of these seismic stations and the study area is shown in Figure 1. The corresponding body-wave magnitude (Mb) values and epicenters are obtained from the PDE of USGS. The values of these seismic parameters were referred to and assumed as standard measurements in reference to the preliminary development of the magnitude formulas. The numbers of duration and amplitude values utilized in each seismic station is as shown in Table 1. The data from the KNSN and USGS are used as initial hypotheses in the fulfillment of the objectives of this paper.

One type of magnitude formula was envisioned to be developed from the KNSN data based on the duration of seismic signal. Generally preliminary development of the magnitude formulas when sufficient data is available is done by means of statistical procedures. The amplitude and duration with the associated epicentral distance data are regressed against corresponding values of a standard and internationally accepted magnitude scale to determine the calibrating function.

Duration magnitude

Preliminary development of this type of magnitude is based has two steps. These are the calibration of the duration magnitude scale for each seismic station and the other is the development of a single formula for all the considered stations. Comparative analysis of the two approaches will generate correction for each seismic station, thereby facilitating the application of a single formula for the whole network for this type of magnitude.

The relation of the magnitude of an earthquake to seismic trace duration is known (Lee et al., 1972; Real and Teng, 1973; Tsumura, 1967; Bakun and Lindh, 1977) to be expressed by the equation:

$$M_D = a \log\tau + b\Delta + c \quad (1)$$

Where M_D is the duration magnitude that is referred from the body-wave magnitude which is taken as the standard magnitude value in this paper, $\log\tau$ is the decadic logarithm of the seismic signal trace duration (τ) in seconds which is measured from the initial onset of the seismic signal up to the time when the signal is twice the background as defined by KNSN, Δ is the epicentral distance in degrees, a, b, c are constants. The determination of equation (1) can be performed in two steps. The first step is conducted without considering the distance, that is:

$$M_D = a \log\tau + k \quad (2)$$

Where k is a constant. The second step is to consider the correction due to the distance to equation (2) which is:

$$M_D - a \log\tau = b\Delta + c \quad (3)$$

For each seismic station for equations (2 and 3). By applying the usual method of least square approximation, the regression constants a, b, c can be determined for each seismic station. The graphical presentation of the steps for the six stations of KNSN is

Table 1. Numbers of duration values utilized in each seismic station.

Station code	QRN	RDF	NAY	RST	MIB	UMR
No. of duration	21	30	43	29	38	40

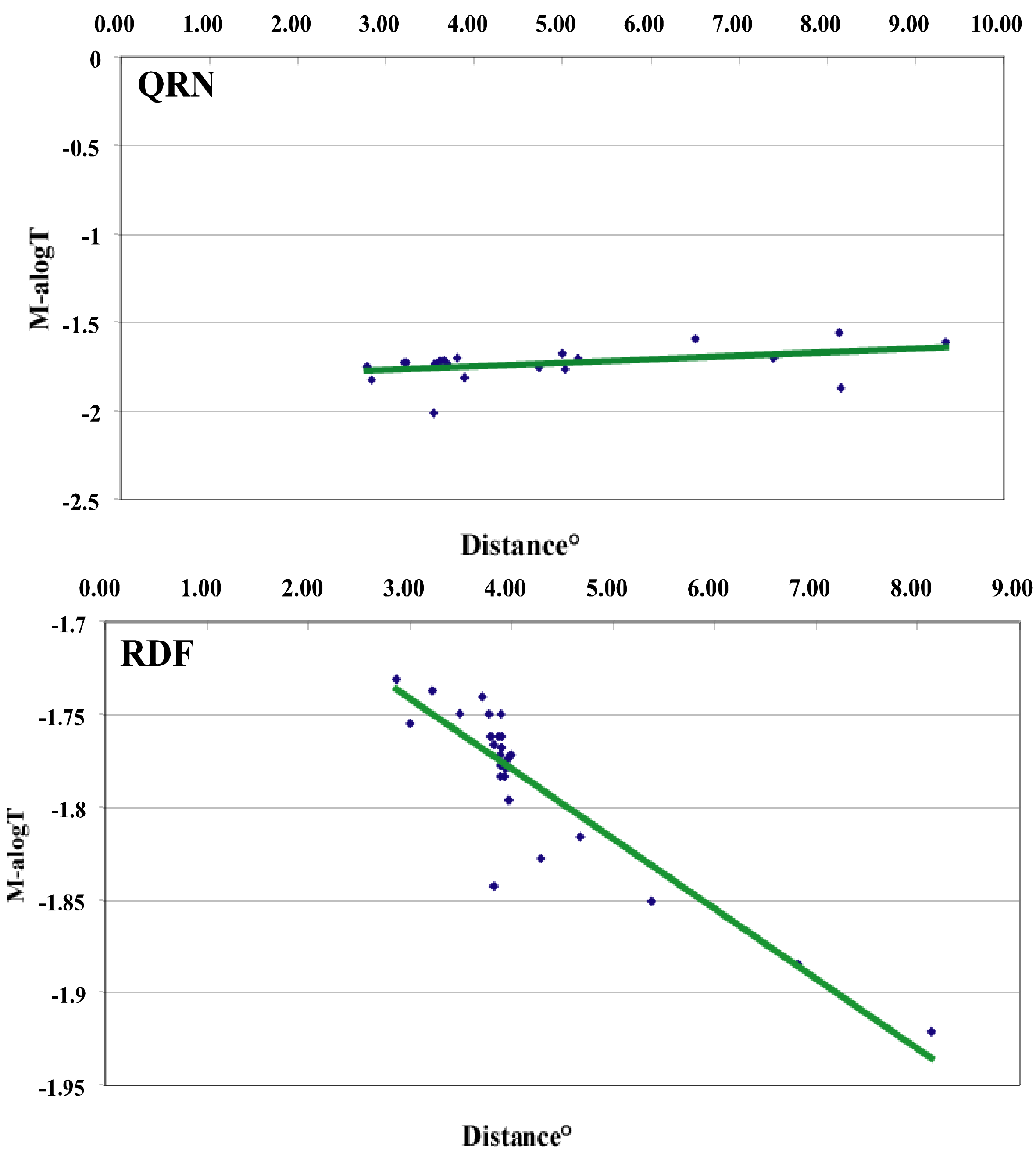


Figure 2a. Plots of the data points between the difference of magnitude (M) and product of the coefficient (a) and logarithm of seismic signal duration (T) against distance° for the QRN and RDF seismic stations of KNSN.

shown in Figures (2a, b, and c). The determination of the single formula from the seismic data of the network follows the same procedures and regression of equations (2 and 3) or (1) by considering all the utilized data from each seismic station. The

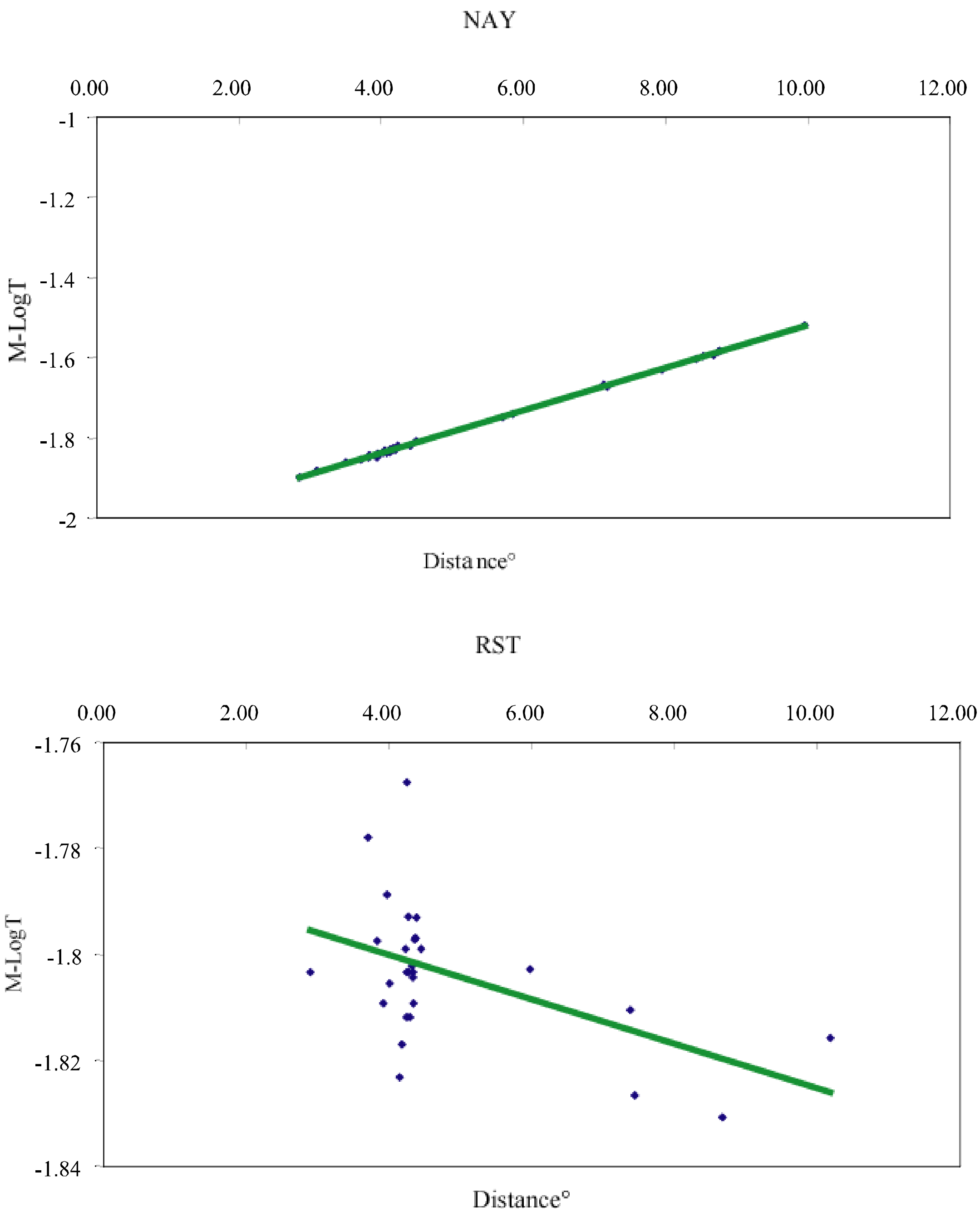


Figure 2b. Plots of the data points between the difference of magnitude (M) and product of the coefficient (a) and logarithm of seismic signal duration (T) against distance° for the NAY and RST seismic stations of KNSN.

development of the single formula is represented as:

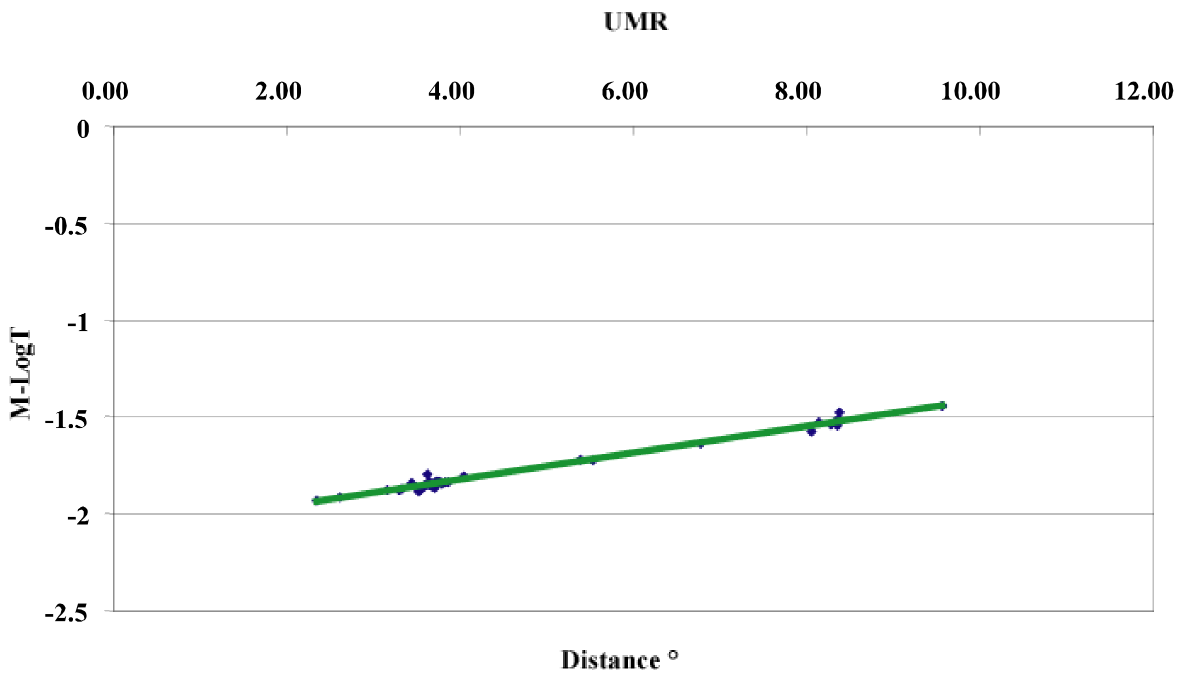
$$M_D - d\log\tau = e\Delta + f \quad (4)$$

Or

$$M_D = d\log\tau + e\Delta + f \quad (4a)$$

For purposes of discussion. The parameters M_D, τ, and Δ are as defined in equation (1), and d, e, f are regression constants to be determined by multiple regression analysis from the total data of the considered seismic stations. The graphical presentation is shown in figure (3).

Station corrections for equation (4a) are determined as follows. Equation (4a) is applied separately to each considered seismic station data to evaluate the magnitude values. Likewise, the representative magnitude equation (1) for each seismic station is also applied to respective data for evaluation. The average of the



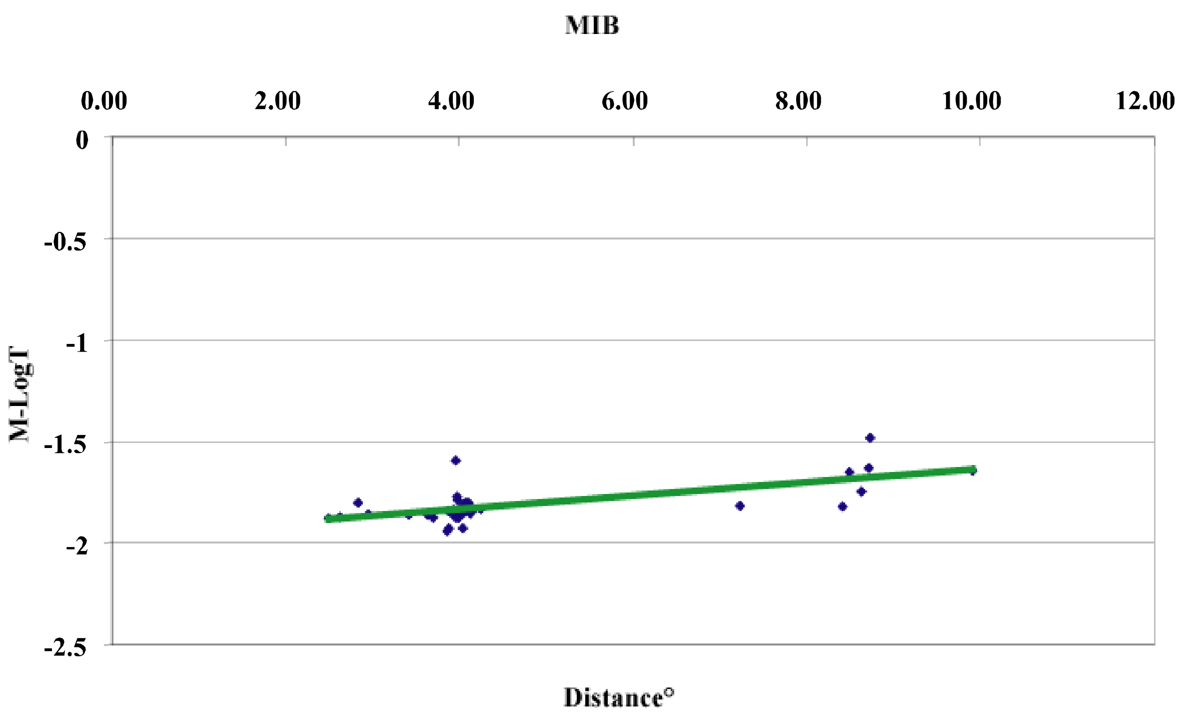


Figure 2c. Plots of the data points between the difference of magnitude (M) and product of the coefficient (a) and logarithm of seismic signal duration (T) against distance° for the UMR and MIB seismic stations of KNSN.

corresponding magnitude differences is then determined and this is taken and assumed as the station correction. The procedure can be expressed as:

$$M_{corr.} = \frac{(d-a_i)\log t+(e-b_i)\Delta+(f-c_i)}{N_i} \quad (5)$$

Where $M_{corr.}$ is the magnitude correction, Ni is the number of data considered for the ith seismic station, with the coefficients and constants as defined previously. Eventually, equation (4) becomes:

$$M_Di = di\log\tau i + ei\Delta i + fi\ M_{corr.}i \quad (6)$$

For the seismic station when reckoned.

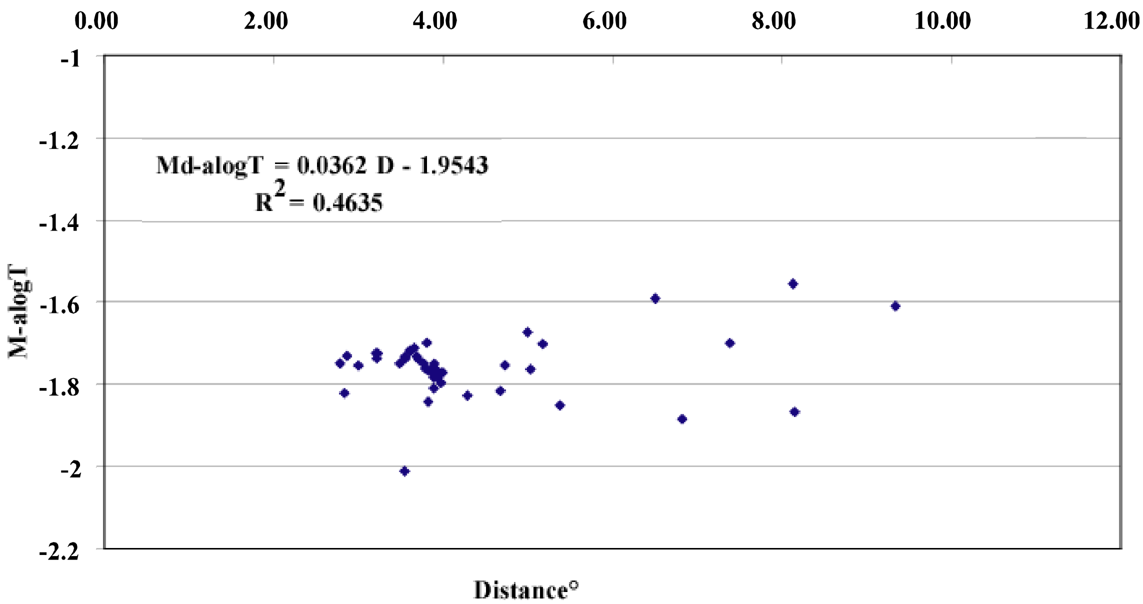


Figure 3. Plots of the single magnitude formulas for duration magnitude scale that are proposed for application by the KNSN in its seismic monitoring activates.

Table 2. Duration magnitude formula for each KNSN seismic station as indicated and for a single representative equation for the considered stations of the network. Each seismic station correction is evaluated from the single formula (total).

Station code	Regression constants			Station correction
	a/d	b/e	c/f	
QRN	2.25	0.036	-0.91	-0.026
RDF	2.54	- 0.035	-1.36	0.35
NAY	2.66	0.053	-2.06	-0.069
RST	2.73	-0.0053	-1.94	0.18
MIB	3.2	0.015	-3.14	0.00
UMR	2.76	0.067	-2.3	-0.017
Total	2.66	0.036	-1.97	

RESULTS

The results of the statistical analyses are shown in Table 2. The table is composed of five columns. The first column is for the seismic stations. The second is for the regression constants. The third is for respective station correction. The results for the preliminary determination of the duration magnitude formula for the KNSN show close values for the coefficient of $log\tau$ as shown in Table 2. However, this conformity is not shown in the correction due to distance. Two seismic stations which are RDF and RST behave differently from the other seismic stations QRN, NAY, MIB, and UMR. The duration magnitude formula for each of the two seismic stations (RDF and RST) seems to indicate increasing seismic signal trace duration with distance.

The result of the validity test in Table 2 indicated that five seismic stations using the single duration magnitude formula can be used. These are QRN, NAY, RST, MIB, and UMR. Station NAY seems to fit better for duration magnitude determination.

DISCUSSION

The KNSN seismic stations are distributed in strategic locations, but relatively near each other. However, it is possible that each seismic station can respond differently to seismic signals due to the influence of some physical factors. These factors could be due to geological and environmental conditions at each station site that could affect the response of the seismic instruments. These possibilities prompted separate analysis of the seismic data which are the seismic trace duration that are gathered and compiled at each KNSN station. The assumptions seemed to be supported and validated by the results as shown in Table 2.

Initially, the characteristics of the respective equations reflect that the station sites are suitable recording the surface waves. Nevertheless, when the seismic data from the other stations (QRN, NAY, MIB, and UMR) are included with RDF and RST data, it gives an appropriate result as indicated by the station corrections. The treatment for the whole data seemed to be appropriate since the results from equation (2) give relatively close values for each seismic station. These considerations including the nearness of the seismic stations reflect that the single duration magnitude is advisable to apply for the KNSN with the inclusion of respective station correction.

Conclusion

The development of the empirical formula for the duration magnitude scale is based on the initial seismic data taken from the KNSN seismic stations. Hence, the magnitude equations are affected by the reliability and accuracy of the utilized seismic data. Comparison of preliminary determination of seismic parameters such as location and magnitude of seismic events from KNSN and USGS indicates some discrepancies. In case of discrepancies, preference is given to the USGS determinations, for the reason that this agency relies on more seismic stations. Some unintentional errors of recordings for the duration value is observable from the KNSN seismic data, based on the corresponding magnitude and distance of earthquake events. The errors could be due to malfunctioning in the instrument response. These errors were considered for correction in relation to the general trend of the graphs and corresponding values from the other seismic stations. It is therefore advisable that automated evaluation of the required data be counter-checked for the realistic assessment of magnitude. Hence, magnitude estimates from the preliminarily developed equations can be considered as conservative values due to encountered constraining factors. The level of accuracy is within the limits of the utilized seismic data and assumptions that were taken regarding similarities in the calibrating functions. Although the station corrections imply the significance and relative accuracy of the proposed formulas, the level of validity can be improved from application for further verification.

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