Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Magnitude Homogenization for International Seismological Centre Magnitudes for South Korea

Soo-jin Jung, Rhajendra Ekaputra, Eric Yee *
Department of NPP Engineering, KEPCO International Nuclear Graduate School,
658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014
**Corresponding author: eric.yee@kings.ac.kr*

1. Introduction

One of the engineering issues that deserves some consideration are the results from seismic hazard analysis that serve as inputs into nuclear power plant safety assessments. This has garnered additional attention because 2016 and 2017 saw some of the largest earthquakes to have ever occurred in South Korea [1-2]. Coincidentally, these large magnitude earthquakes had epicenters very close to several nuclear power plants located along the eastern coast. However, since South Korea is not considered a highly seismic region, many assumptions are typically made for localized earthquake studies, such as seismic hazard analysis.

One of the key components in a seismic hazard analysis is the earthquake catalog used to derive a variety of engineering parameters used in the analysis. These earthquake catalogs contain earthquake event information, usually from a variety of sources. Because of this, much of the information may not be harmonized. For example, some seismological agencies may use moment magnitude, M_W, or local magnitude, M_L, in describing how large an earthquake is [3-4]. Since there are many magnitude types, these earthquake catalogs can contain events that are difficult to compare. This preliminary study attempts to develop relationships to help homogenize popular earthquake magnitudes in a typical South Korean earthquake catalog.

2. Methods and Results

To construct an earthquake catalog for this preliminary study, earthquake data were compiled from the International Seismological Centre, ISC [5-6]. Data was obtained from a region up to 200 kilometers from the South Korean border including Dokdo. The data coverage is bounded by latitudes 31°S to 41°N and Longitudes 122° to 134° E for a period stretching as far back as 1900 to 2020, which is the maximum time window for the International Seismological Centre. The average crustal thickness of the South Korean peninsula is 32.55 km and the standard deviation is 3.3 km, therefore the search conditions are within 35.9 kilometers depth. Given this, a limiting depth of 45 km was assigned as a boundary condition. Additionally, only events with a magnitude of 2.5 or higher was considered. These constraints yielded 753 earthquake events. Interestingly, the ISC have their own magnitude data attributed to earthquake events. They typically provide surface wave magnitudes, M_S, and body wave magnitudes, m_b [7-8].

ISC also has a sub-project called ISC-GEM, which basically takes a subset of earthquake events in the ISC database and apply more advanced techniques to derive hypocenter and magnitude estimates [5-6]. The events that qualify for ISC-GEM consideration are those with high data quality. The ISC-GEM is a homogenized earthquake catalog, with a unifying magnitude of M_W. This catalog yielded 15 events.

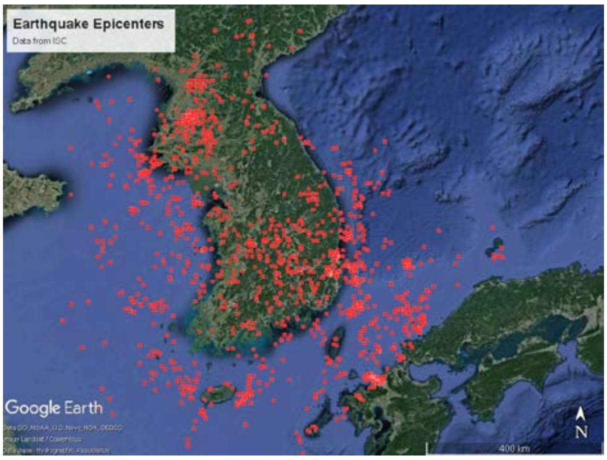

Fig. 1. Earthquake epicenters of data from ISC.

An additional earthquake catalog utilized for this study is the Global CMT project. The Global CMT database uses centroid moment tensors to estimate magnitude related parameters and so is considered the best comparison for earthquake magnitudes. Because of this, there are not many earthquakes in Global CMT catalog and their data start from 1976.

These ISC magnitudes are compared to the M_W data from Global CMT project for the same earthquake [9-10]. A linear regression is made to estimate a moment magnitude proxy, $M_{W,proxy}$, from the base ISC magnitudes.

An example is given in Figure 2. The figure shows the correlation between M_W and $m_{b,ISC}$. There were a total of 45 earthquakes that had both a M_W and $m_{b,ISC}$. It would appear the paired data had a minimum $m_{b,ISC} > 3.0$ and $M_W > 3.5$, and reaches a limit at $m_{b,ISC} \sim 5.9$ and $M_W \sim 6.6$, suggesting potential magnitude saturation effects. These higher magnitude events are from Japan. The correlation appears somewhat linear but slightly off from the 1-to-1 line. Interesting because a common belief is that m_b should be very close to M_W at low and intermediate values. Note M_W was mostly utilized for it's ability to avoid magnitude saturation, that is to perform better at higher magnitude values.

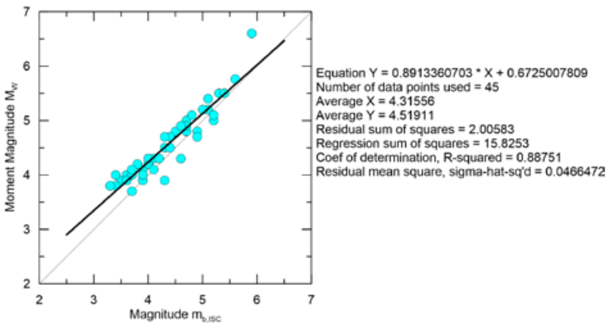

Fig. 2. Correlation between M_W and $m_{b,ISC}$.

Figure 3 shows the correlation between M_W and $M_{S,ISC}$. There were a total of 29 earthquakes that had both a M_W and $M_{S,ISC}$. It would appear the paired data had a minimum $M_{S,ISC} > 3.0$ and $M_W > 4.0$, and reaches a limit at $M_{S,ISC} \sim 7.0$ and $M_W \sim 7.1$. Strange that there is no strong magnitude saturation effect at the larger magnitude range. Similar to $m_{b,ISC}$, the correlation appears somewhat linear, but is significantly off the 1-to-1 line. However, the higher magnitudes appear to follow the 1-to-1 line better. Again, the higher magnitude events belong to earthquake events in Japan.

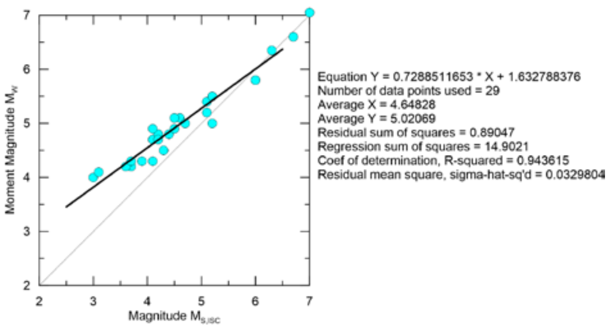

Fig. 3. Correlation between M_W and $M_{S,ISC}$.

In summary, the magnitude homogenization parameters are listed in Table I.

Table I: Gutenberg-Richter parameters for each zone.

Magnitude type	Number of earthquakes	slope	intercept
$m_{b,ISC}$	45	0.891	0.673
$M_{S,ISC}$	29	0.729	1.633

3. Conclusions

In this study, magnitude homogenization relationships for popular ISC magnitude, namely $m_{b,ISC}$ and $M_{S,ISC}$ were regressed from a variety of earthquake catalogs. Both showed a linear correlation, but both were off from a 1-to-1 line. Even though most of the large magnitude events were in situated closer to Japan, the data did not show strong magnitude saturation effects. These findings help in the initial stages of a nuclear power plant seismic safety assessment and seismic hazard analysis.

Acknowledgement

This research was supported by the 2023 Research Fund of the KEPCO International Nuclear Graduate School (KINGS), the Republic of Korea.

REFERENCES

[1] United States Geological Survey, https://earthquake.usgs.gov/earthquakes/eventpage/us2000bnrs/executive. 2017. (Accessed March 16, 2023)
[2] United States Geological Survey, https://earthquake.usgs.gov/earthquakes/eventpage/us10006p1f/executive#executive. 2016. (Accessed March 16, 2023)
[3] Hanks, T.C., Kanamori, H. A Moment magnitude scale, Journal of Geophysical Research, Vol. 84 2348–2350, 1979.
[4] Richter, C.F. An Instrumental Earthquake Magnitude Scale, Bulletin of the Seismological Society of America, Vol. 25, 1–32, 1935.
[5] Storchak, D.A., D. Di Giacomo, I. Bondár, E.R. Engdahl, J. Harris, W.H.K. Lee, A. Villaseñor and P. Bormann. Public Release of the ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009). Seism. Res. Lett., 84, 5, 810-815, (2013)
[6] Bondár, I., E.R. Engdahl, A. Villaseñor, J. Harris and D.A. Storchak, 2015. ISC-GEM: Global Instrumental Earthquake Catalogue (1900-2009): II. Location and seismicity patterns, Phys. Earth Planet. Int., 239, 2-13, 2015.
[7] Gutenberg, B. Amplitudes of surface Waves and magnitudes of shallow earthquakes, Bulletin of the Seismological Society of America, Vol. 35, 3–12, 1945.
[8] Gutenberg, B. Amplitudes of P, PP, and S and magnitude of shallow earthquakes, Bulletin of the Seismological Society of America, Vol. 35, 57–69, 1945.
[9] Dziewonski, A. M., Chou, T.-A., Woodhouse, J. H. Determination of earthquake source parameters from waveform data for studies of global and regional seismicity, Journal of Geophysics Research, Vol. 86, 2825-2852, 1981.
[10] Ekström, G., Nettles, M., Dziewonski, A.M. The global CMT project 2004-2010: Centroid-moment tensors for 13,017 earthquakes, Physics of the Earth and Planetary Interiors, Vol. 200-201, 1-9, 2012.