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Magnitude Homogenization for Agencies Relevant to South Korea

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1. Introduction

There have only been 8 earthquakes with a local magnitude of 5.0 or greater in the past 45 years within the borders of South Korea. This makes it very difficult to conduct earthquake safety studies as the quantity are not large, but the recorded magnitudes are not small. However, the more recent earthquakes, the 2016 Gyeongju and 2017 Pohang earthquakes, caused many to reconsider the seriousness of earthquake safety in South Korea, especially when it involved nuclear power plants [1-2]. This was because the 2016 Gyeongju and 2017 Pohang earthquakes had epicenters near the nuclear power plant complexes on the eastern edge of South Korea.

One mitigating measure when there is not a lot of data to work with is to improve or modify the data that is available to another metric that is relevant to the study. One of the inputs into a nuclear power plant seismic safety assessment are the results from a seismic hazard analysis [3]. A common approach to seismic hazard analysis is to use compile an earthquake catalog to help derive the seismicity and magnitude parameters for later analysis. However, earthquake catalogs tend to have a variety of magnitude types as different seismological agencies have different protocols in how they store data. The most common magnitude types are moment magnitude, M_W, surface wave magnitude, M_S, body wave magnitude, m_b, or local magnitude, M_L, in describing how large an earthquake is [4-7]. The practice of unifying an earthquake catalog to showcase one magnitude type is known as magnitude homogenization. This study attempts to provide magnitude homogenization regressions for magnitudes from seismological agencies most relevant to the South Korean region, namely from South Korea, North Korea, and Japan.

2. Methods and Results

Several earthquake data catalogs will be required to develop the appropriate magnitude homogenization relationships for the South Korean region. Specific catalogs used in this study include the bulletin by International Seismological Centre (ISC) and the Korea Meteorological Agency (KMA) [8]. The ISC earthquake catalog is a global catalog of seismic events recorded from all over the world starting from around 1900 and is updated periodically. Many international seismological agencies submit data to the ISC, including KMA, Japan Meteorological Agency (JMA), and Earthquake Administration of DPR Korea (KEA). An additional catalog considered is the Global CMT project (GCMT). This is essentially an online earthquake catalog for large earthquakes with good estimates for magnitude. Data starts from 1976. They are most used for their M_W data. This is in contrast to magnitude data from KMA, JMA, and KEA, which are primarily of the local magnitude type.

A search is made within these catalogs to compile a set of earthquakes relevant to the South Korean region. Events from the beginning of 1900 until the end of 2020 were considered. The search region was bounded to within 200 km of the mainland border and islands of South Korea within 31° to 41° N and 122° to 134° E. Depth was limited to 30 km as any earthquake deeper could be below the crust and from mantle materials. Additionally, when the option was available, a minimum magnitude of 2.5 was selected as it is assumed earthquakes with magnitudes at 2.5 or less would not influence magnitude homogenization model development and this was to help constrain events from KMA, JMA, and KEA. There will be no distinction between a main shock, foreshock, or aftershock. Figure 1 shows a map of all the earthquakes from all three agencies.

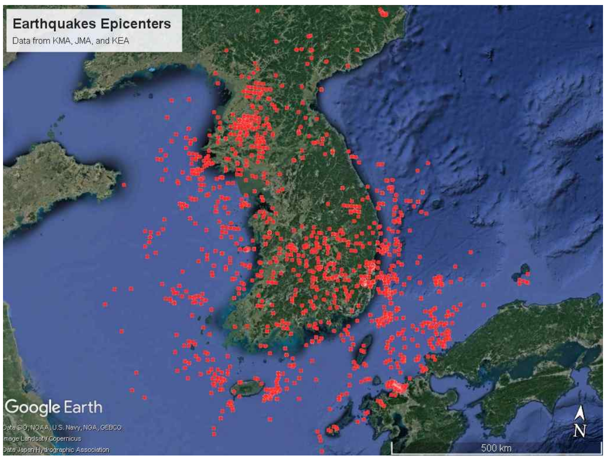

Fig. 1. Epicenters of earthquakes compiled from KMA, JMA, and KEA.

Since M_W is the most reliably based moment magnitude for engineering studies, M_W will be the unifying magnitude type, represented as $M_{W,proxy}$.

Figure 2 shows the magnitude homogenization results for KMA. A total of 48 even pairs were found in the compiled catalog. These data pairs show linear sloping behavior with M_W from about $M_{L,KMA} > 4.0$. However, at magnitudes below that, any change in the KMA magnitude does not change the moment magnitude. This can be considered a type of magnitude saturation.

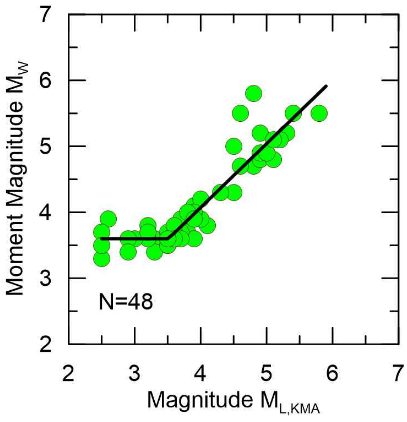

Fig. 2. Correlation between $M_{L,KMA}$ and M_W.

Figure 3 plots the results when considering data from JMA. There are significantly more data pairs, at 114 events, and there appears to be a linear relationship across the range of values. The large magnitude events are from Japan and do not show magnitude saturation.

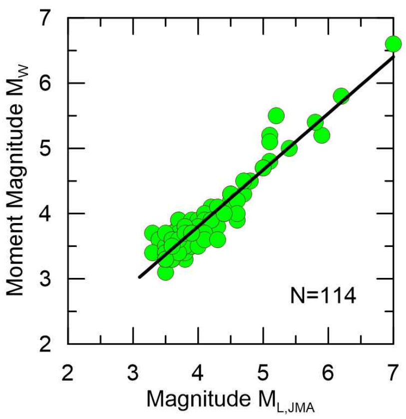

Fig. 3. Correlation between $M_{L,JMA}$ and M_W.

Figure 4 plots the results when considering data from KEA. There are significantly fewer data pairs, at 14 events, and there appears to be a linear relationship across the range of values. However, given the small number of events, this is no surprise.

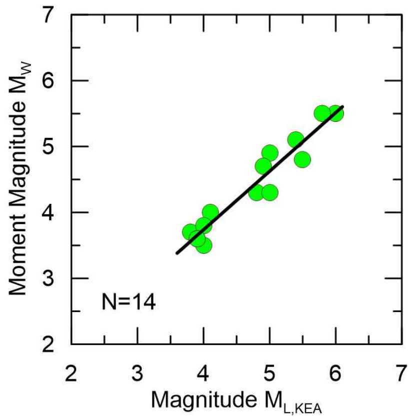

Fig. 4. Correlation between $M_{L,KEA}$ and M_W.

3. Conclusions

In this study, based on the linear relationship of Mw with Ml data from KMA (KMA > 4.0 conditions), JMA, and KEA identified, magnitude homogenization regressions are displayed to help give an additional tool in seismic hazard analyses as input into nuclear power plant seismic safety assessments. Recorded earthquakes from South Korea, North Korea, and Japan all show varying levels of behavior and range, although a majority of the data plot in a linear fashion.

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