Magnitude Homogenization for the Greater Egyptian Region

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1. Introduction

Egypt is located in a region of moderate seismic activity compared to other highly active areas such as Japan or Indonesia. Nevertheless, the country has experienced damaging earthquakes. Recent moderate events in the Gulf of Aqaba (2015 M_W 5.6, 2016 M_W 5.3) further emphasize the importance of seismic evaluation. The construction of the El Dabaa Nuclear Power Plant (NPP) on the Mediterranean coast highlights the necessity of reliable seismic hazard assessment to ensure the safety of critical infrastructure.

A major challenge in seismic hazard analysis lies in the heterogeneity of earthquake magnitude types reported by different agencies. Magnitudes such as M_d, M_L, mb, M_S, and M_W are inconsistently distributed across catalogues, leading to systematic bias in seismicity characterization. To address this, magnitude homogenization is applied to convert all reported magnitudes into a unified M_W scale, which is widely recognized for its physical basis and stability across a broad magnitude range.

The objective of this study is to compile a homogenized earthquake catalogue for Egypt by integrating multiple national and international sources, applying established conversion equations, and ensuring a consistent M_W representation suitable for probabilistic seismic hazard analysis (PSHA).

2. Methods and Results

2.1 Catalog Compiling

The earthquake dataset used in this study was compiled from the online Bulletin of the International Seismological Centre (ISC) [1-2], covering global events from 1900 to 2023. The ISC Bulletin integrates data from various seismological agencies, including the Global Centroid Moment Tensor (GCMT) project [3]. In addition, the ISC-GEM catalog [4], which provides improved parameter solutions for a subset of ISC earthquakes, was incorporated to enhance data reliability. After compilation and homogenization, a unified catalog of 39,148 earthquake events was established for analysis.

2.2 Magnitude Homogenization Framework

The magnitude homogenization process was designed as a hierarchical framework to ensure consistency and reliability. At the top of the hierarchy, M_W values from the GCMT catalogue were directly adopted, as they are based on robust waveform inversion and are widely regarded as the most reliable global dataset. These values served as the benchmark.

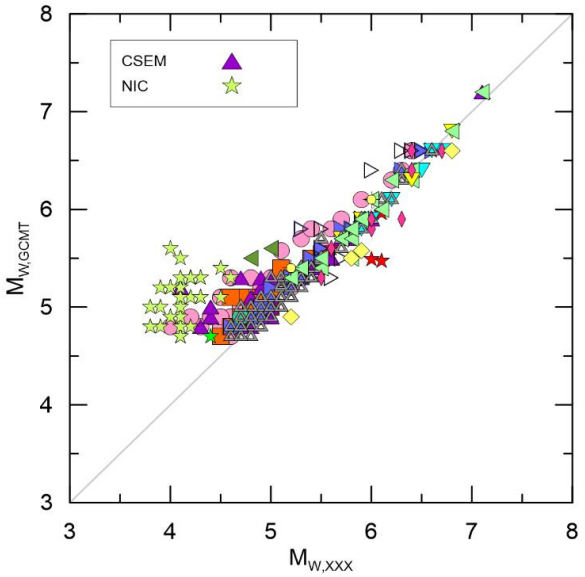

Fig. 1. Regression between M_W (GCMT) and M_W (Other Agencies)

Next, M_W values from other international agencies, such as the ISC and National Earthquake Information Center (NEIC), were included after comparison with GCMT to confirm consistency. Where significant systematic deviations were observed, such as in European-Mediterranean Seismological Centre or Cyprus Geological Survey Department data, those values were excluded from the homogenized catalogue. This selective approach ensured that only reliable M_W estimates contributed to the dataset.

For events without reported M_W, such as M_S and mb, a set of regression relationships for African continent using orthogonal distance regression were applied [5]. These equations were specifically calibrated for African datasets and thus considered highly applicable for Egyptian seismicity. Accordingly, M_S and mb reported

by ISC and NEIC were transformed into Mw using these relations.

When neither M_W nor convertible M_S/mb were available, regressions focused specifically on the Egyptian catalogue were applied [6]. This study shows multi-step conversions from local magnitudes (M_d, M_L) to M_W through the intermediate calculation of seismic moment. These equations accounted for regional conditions, local instrumentation, and completeness thresholds, making them suitable for filling gaps in the historical record.

The final hierarchal method for homogenization is therefore:

1. Direct Mw from GCMT,
2. Mw from other agencies,
3. Conversions for M_S and mb [5],
4. Conversions for M_d and M_L [6].

This systematic approach maximized the reliability of the final catalogue while preserving as many events as possible. In total, the process covered nearly all recorded events in Egypt during the instrumental period.

2.3 Seismicity Characteristics after Homogenization

The homogenization process yielded a catalogue of 25,979 earthquake events expressed consistently in M_W. Among these, 654 events retained direct GCMT M_W values, while 3,024 events were based on M_W from other agencies. A total of 6,989 events were converted using M_S and mb regressions [5], primarily mb and M_S reported by ISC and NEIC. The largest share, 15,312 events, came from local magnitude conversions [6]. This reflects the predominance of M_d and M_L in Egyptian and regional seismic networks.

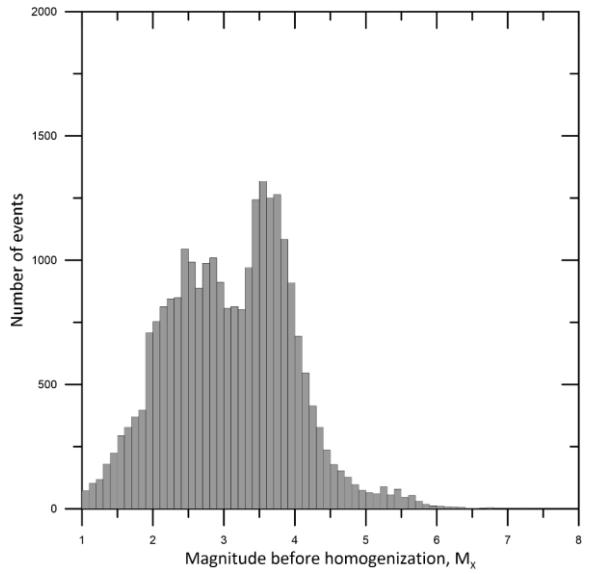

Fig. 2. Magnitude-frequency distribution before magnitude homogenization

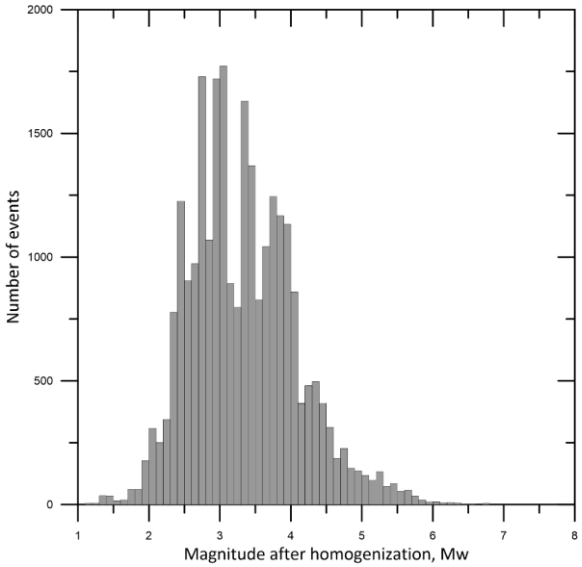

Fig. 3. Magnitude-frequency distribution after magnitude homogenization

Before homogenization, the earthquake catalogue showed irregular patterns due to the mixture of magnitude scales. Events with mb and M_S often underestimated the true size of larger earthquakes because of magnitude saturation, while local magnitudes created inconsistencies in the low-to-moderate range. After homogenization, the distribution became more coherent, with magnitudes clustering around M_W 3.1–3.2. This shift is consistent with the regression coefficients used for conversion and does not represent distortion of the dataset, but rather correction toward a uniform Mw scale.

3. Conclusions

This study compiled and homogenized a comprehensive earthquake catalogue for Egypt, totaling nearly 26,000 events. By applying a hierarchical procedure that prioritized direct M_W values and incorporated regional regressions from other studies, the catalogue was uniformly expressed in M_W. The homogenized catalogue eliminates systematic bias and artificial discontinuities across magnitude ranges, providing a consistent seismic database. This unified dataset forms a robust basis for seismicity analysis and PSHA, directly supporting the site evaluation and safety design of the El Dabaa NPP and other nuclear facilities in Egypt. Beyond immediate applications, the catalogue also establishes a standardized reference for future seismic studies, underlining the necessity of magnitude homogenization as a prerequisite for reliable hazard assessment.

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REFERENCES

[1] D. A. Storchak, J. Harris, L. Brown, K. Lieser, B. Shumba, R. Verney, D. Di Giacomo, and E. I. M. Korger, Rebuild of the Bulletin of the International Seismological Centre (ISC), Part 1: 1964–1979, Geoscience Letters, Vol. 4, pp. 1–9, 2017.
[2] D. A. Storchak, J. Harris, L. Brown, K. Lieser, B. Shumba, and D. Di Giacomo, Rebuild of the Bulletin of the International Seismological Centre (ISC)—Part 2: 1980–2010, Geoscience Letters, Vol. 7, pp. 1–12, 2020.
[3] G. Ekström, M. Nettles, and A. M. Dziewonski, The Global CMT Project 2004–2010: Centroid-Moment Tensors for 13,017 Earthquakes, Physics of the Earth and Planetary Interiors, Vol. 200–201, pp. 1–9, 2012.
[4] D. A. Storchak, D. Di Giacomo, E. R. Engdahl, J. Harris, I. Bondár, W. H. K. Lee, P. Bormann, and A. Villaseñor, The ISC-GEM Global Instrumental Earthquake Catalogue (1900–2009): Introduction, Physics of the Earth and Planetary Interiors, Vol. 239, pp. 48–63, 2015.
[5] G. A. Weatherill, M. Pagani, and J. Garcia, Exploring Earthquake Databases for the Creation of Magnitude-Homogeneous Catalogues: Tools for Application on a Regional and Global Scale, Geophysical Journal International, Vol. 206, pp. 1652–1674, 2016.
[6] H. M. Hussein, K. M. Abou Elenean, I. A. Marzouk, A. Persean, I. M. Korrat, E. Abu El-Nader, G. F. Panza, and M. N. El-Gabry, Integration and Magnitude Homogenization of the Egyptian Earthquake Catalogue, Natural Hazards, Vol. 47, pp. 525–546, 2008.