AN ANALYSIS OF PAKISTAN'S LOCAL NETWORK CATALOG OF EARTHQUAKE FOR THE PERIOD OF 1905-2007

Farhana Sarwar , Saleem Iqbal and LalaRukh Kamal
Department of Mathematics, University of Balochistan, Quetta, Pakistan
e-mail: fs1005, saleemiqbal81, lalarukhkamal@yahoo.com.

ABSTRACT : *Pakistan is situated in a highly seismically active region and has experienced many disastrous earthquakes in the past. The October 2005 Muzaffarabad Earthquake M7.4 enhanced need for earthquake prediction studies and seismic hazardanalysis. But before one proceed in such investigation it is essential to examine and report on the spatial and temporal homogeneity and completeness of the earthquake catalog as they are a valuable result of fundamental seismological practice and form the basis for icity,seismotectonic, seismic risk and hazard investigation. This paper is focused on the analysis of local catalog of Pakistan referred from the PMD (Pakistan metrological department) covers a period of 1905 to 2007 and its comparison is done with the Global Catalog of National Earthquake Information Centre (NEIC). Pakistan and adjoining region lying between longitude 60^{o}E to 78^o E and latitude 20^{o}N to 45^{o}N is selected for the study. From the NEIC catalog, a Sub-catalog is obtained for Pakistan and surrounding region, tit contains 8635 events from 1963 to2004. Finally to get a rather homogeneous catalog for the region we have merged the two catalogs by considering different data properties and different data analysis techniques prepared by different data collection agencies. The results of this study can be* employed for the earthquake prediction research.

Index Terms: Earthquake Catalogs, Frequency-Magnitude Relation, PMD Catalog, NEIC Catalog.

INTRODUCTION

EARTHQUKE catalog are a valuable result of fundamental seismological practice and they form the basis for seismicity, seismotectonic, seismic risk and hazard investigation. Before one proceed in such investigation it is essential to examine and report on the spatial and temporal homogeneity and completeness of the catalog. This is because earthquake catalogs are produced by the recording of seismic waves in seismological networks that change in time and space with varying operational practice and procedures. It is a common knowledge that catalogs have errors, whose identification and elimination is desirable [1]. It suffers from the three types of man-made seismicity changes identified in [2], namely detection changes, reporting changes, and magnitude shifts, these errors can also be distinguished into systematic and random ones and in 1995 this is comprehensively discussed in [3]. Systematic errors can be associated to changes in the data acquisition system or in the methods for the determination of earthquake parameters. Random errors correspond generally to the uncertainty of determination and to possible mistakes made during data input process. Most of the errors could not be corrected without reference to the original source records. However many of them could be detected when two or more catalog sources are available. It is necessary to compare catalog available for equivalent and nonequivalent entries, and to compare values of parameters (e.g. magnitudes) from different sources.

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In this paper we have considered two catalogs of earthquakes to analysis and report on the spatial and temporal homogeneity and completeness of the local catalog, the local catalog referred from the PMD (Pakistan Metrological Department) and the Global Catalog of National Earthquake Information Centre (NEIC) of U.S.A. The information contained in the local catalog covers a period of 1905 -2007 and information in the Global catalog contains 8635 events from 1963 to2004.

A. PMD (Pakistan Metrological Department) Catalog:

The PMD instrumental database is comprised of historical and instrumentally recorded earthquakes. Only body wave magnitude m_b is assigned to the recorded earthquakes. The PMD seismic recording network is operational this catalog contains events since 1905 and previous records are taken from International Seismological Centre (ISC). In the1960's World Wide Standardized Seismic Network (WWSSN) stations were installed at Peshawar, Islamabad and Quetta. Due to this network PMD recorded teleseismic earthquakes and distant earthquakes records are available in PMD data base. In our study the information contained in the local catalog covers a period of 1905 to2007 but it is lacking information about exact time of an event, .i.e., time in **hour:min:sec.** It contains 1741 events. Historical data is almost complete for magnitudes 4.0 to 5.5. The objective of this cataloging is to provide the original phase data. Although the data set reports more seismic events than NEIC but it is lacking determination of magnitude (M_s in particular).

II-B. National Earthquake Information Centre (NEIC) Catalog:

Earthquake catalog prepared by National Earthquake Information Centre (NEIC) of e US Geological Survey was found very reliable and complete for magnitude M>4.0 from 1964 onward , when the World Wide Seismic Station Network (WWSSN) of (USGS) became operational. From the global catalog NEIC a Sub-catalog is obtained for Pakistan and surrounding region lying between latitude 20^{o}N to 45^{o}N and longitude 60^{o}E to 78^{o}E, which contains 9167 events from 1963 to 2004.

RESULTS AND DISCUSSION

We have done comparison , data analysis and merging of two catalogs PMD and NEIC by using different data properties and different data analysis techniques prepared by different data collection agencies. We have used Computer

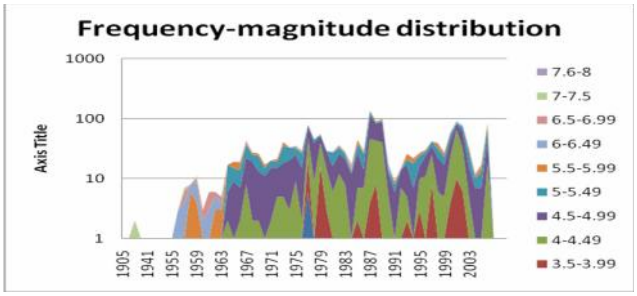
programmes like CompiCat [4], Microsoft Excel and Seismic Eruption for the analysis to get a rather homogeneous catalog. The comparison gives us a better understanding to avoid catalog errors and uncertainties as they render invalid conclusion derived in a study based on catalog of earthquakes. In this paper we have used different presentation techniques for analysis which include plots of seismicity, time versus magnitude, and Gutenberg-Richter relationship and depth distribution versus time. Before merging the two catalogs, the NEIC catalog was again updated to 22-06-2007, then the two catalogs PMD and NEIC are merged together keeping in view identification of common events that is when merging the PMD and NEIC data sets, two records from two different catalogs are considered as records of the same event if the difference in their hypocentral coordinates; time and magnitude do not exceed a set of predefined thresholds, .i.e., if they satisfy the following condition:

- Time = 1 minute
- Longitude = 0.5^{o}
- Latitude = 0.5^{o}
- Depth = not limited
- Magnitude = not limited [5], [6] 1614 events were found duplicate.

III-A. Frequency magnitude relations:

A frequency magnitude relation shows the number of earthquakes per year. The completeness of the catalogs can be observed as shown in Fig (1-2) before merging them and

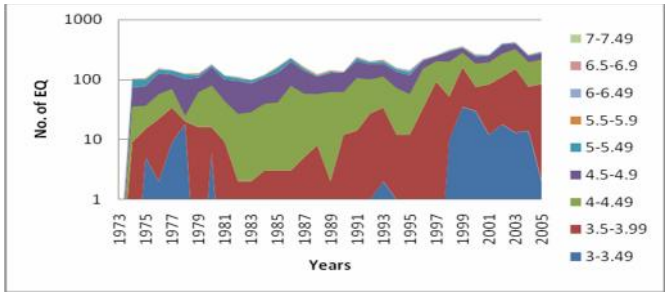
Fig.1 is showing completeness of the NEIC catalog



for different magnitudes. The catalog is quite complete for magnitudes 3.5 to 5.0, but for magnitude less than 3.5 and greater than 5.0 this catalog is incomplete.

Fig.2 is showing frequency magnitude graph of PMD catalog.

For smaller magnitudes3.00 to3.99 the catalog is incomplete.



Magnitude 4.00 to 4.99 is quite complete after 1963. Few records of magnitude 5.00 to 5.99. From 1992 and onwards the catalog is quite complete for magnitude 4.00 to 5.49.1 is showing completeness of the NEIC catalog for different magnitudes. The catalog is quite complete for magnitudes 3.5 to 5.0, but for magnitude less than 3.5 and greater than 5.0 this catalog is incomplete.

Figure 1 . The Frequency Magnitude Relation for the Merged Catalog.

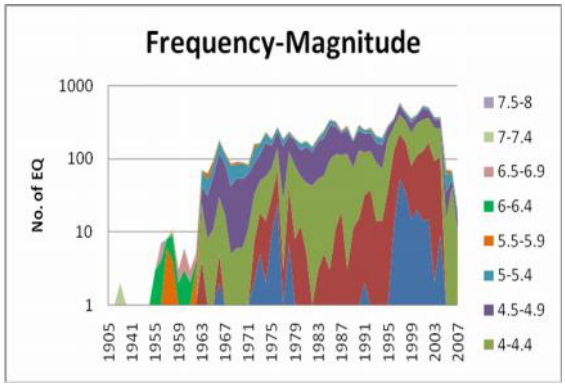


Fig.3 is showing the frequency magnitude relation after we have merged them the total number of earth quakes of different magnitude in the NEIC catalog from 1963 to 2004, PMD catalog showing 1741 events and merged catalogs showing a total of 10, 450 events respectively.

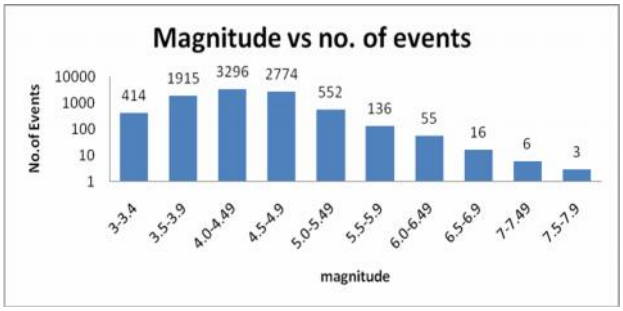
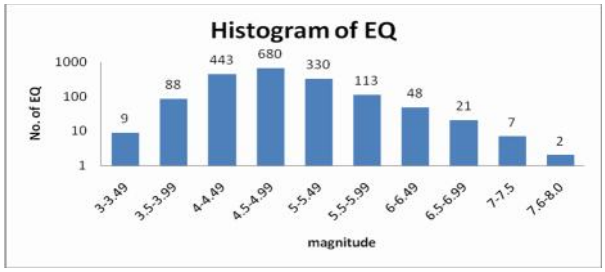


Figure 2. The Histogram Showing Total Number of Earthquakes of Different Magnitude in the NIEC Catalog

Figure 3. The Histogram Showing Total Number of Earthquakes of Different Magnitude in the PMD Catalog.



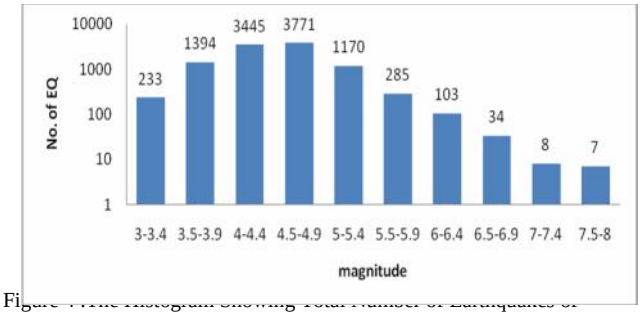


Figure 4. The Histogram Showing Total Number of Earthquakes of Different Magnitude in the Merged Catalo

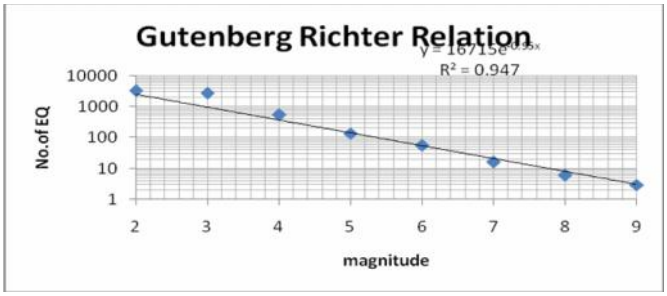


Figure 5. The NEIC Catalog of Earthquakes: The Gutenberg-Richter Plot.

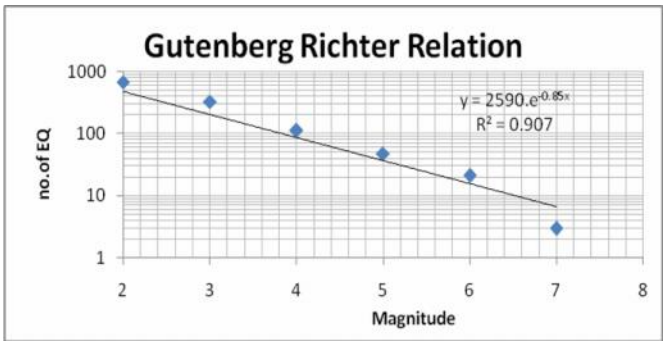


Figure 6. The PMD Catalog of Earthquakes: The Gutenberg-Richter Plot.

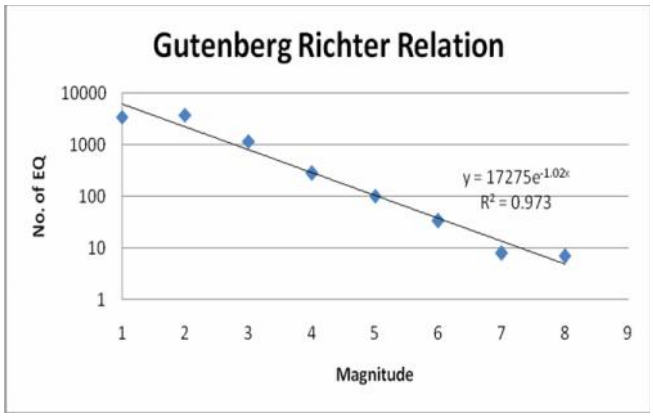


Figure 7.The Merged Catalog: The Gutenberg-Richter Plot.

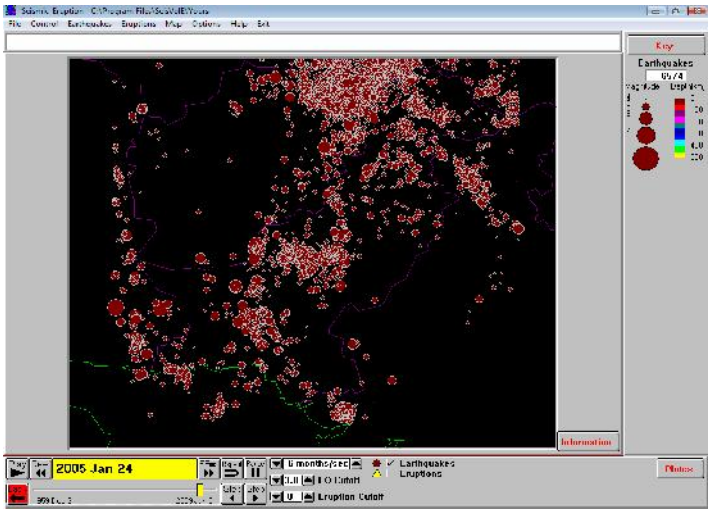


Figure 8. The Seismicity of Pakistan According to NEIC Catalog

III-C. Gutenberg Richter Relation:

Gutenberg and Richter [7] found that the frequency of earthquake occurrence is related to their magnitudes. The frequency magnitude relation is given by:

$$\log_{10}N = a - bM$$

where M is magnitude, N is the number of earthquakes of magnitude≥ M, **a** is a constant, and **b** determines the relative number of earthquakes of different magnitudes. The parameter **b** is often referred to **b**-slope or **b**-value. Many studies of earthquake statistics show that in the normal cases the value of b is approximately 1.0, which means that the number of earthquakes increases tenfold for each decrease of one magnitude unit. Thus, if an area produces one earthquake of magnitude 4 in a month, it would produce 10 earthquakes of magnitude 3, 100 earthquakes of magnitude 2 and 1000 earthquakes of magnitude 1 in one month. Therefore, smaller the magnitude of the earthquakes, greater the amount of seismic data one can record . This relationship has been found to apply to particular regions as well as to the world as a whole. The constant a reflects the absolute level of seismicity of the region.

Fig.7 is showing the Gutenberg -Richter relation for NEIC catalog with value of the R^2 statistic equals about 94% and reasonable completeness of the catalog at the magnitude level about magnitude 4.5

Fig.8 for PMD catalog is showing R^2 = 90 %. As could be judged from this figure, a systematic, although evidently far from complete, record of earthquakes in the catalog show up a near perfect linear plot of the Gutenberg -Richter relationship down to magnitude 3.0 (the R-squared statistic equals about 90%). This kind of consistency of the PMD catalog and reasonable completeness of the NEIC at the magnitude level about 4.5 suggests combining the two data sources for a better characterization of seismic activity in the vicinity of Pakistan.

Fig.9 shows that the merged catalog is quite consistent and gives R^2 = 97 %. This is the initial data source of further analysis.

III-D. The Spread of Seismicity and Occurrence of Earthquakes at Different Depths:

We have used compicat program and seismic eruption programm to show the seismicity of Pakistan for the two catalogs.

Fig.10 is showing the epicenters as well as the seismicity of Pakistan and some parts of the neighbouring countries according to NEIC catalog. The size of the dot indicates magnitude of the earthquake, showing 6574 events.

Fig.11 is showing the spread of seismicity according to PMD catalog. It can be seen from Fig. 10 and Fig.11 that the two catalogs are nearly identical.

The Fig.12 is the spread of seismicity after merging of catalogs. The analysis shows that the area comprising latitude from 30°N to 40°N and longitude 65°E to 78°E

Fig.13 is showing magnitude $m_1 = m_b$ versus depth for merged catalog. The occurrence can be observed up to a depth of 250 km but it is also obvious from the Fig.13 that most earthquakes are shallow ones

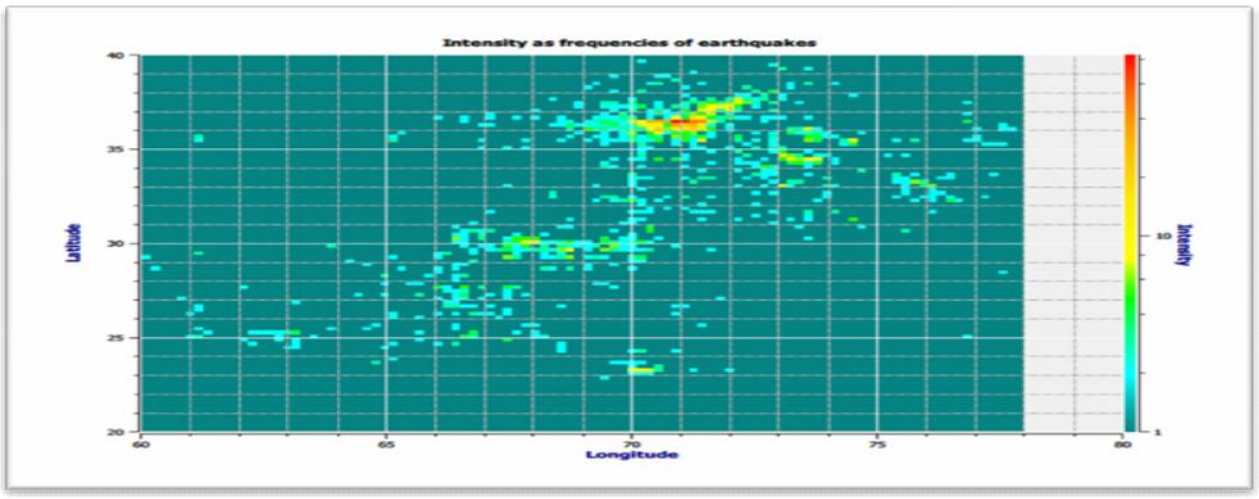


Figure 9. The Spread Seismicity According to PMD Cata

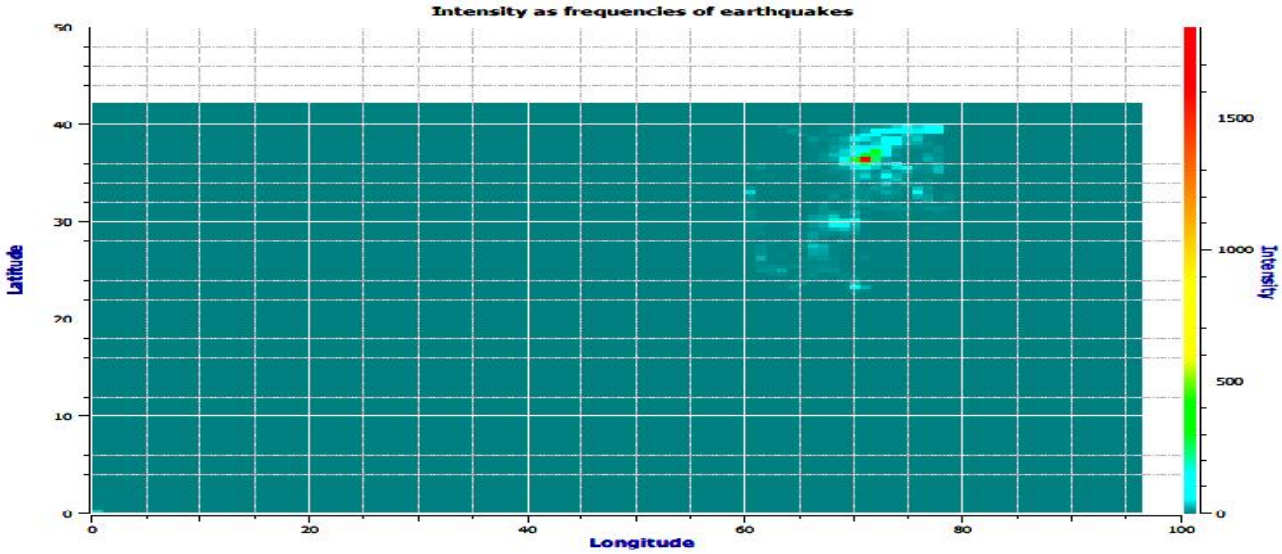


Figure 10. Showing the Spread of Seismicity after Merging of Catalogs

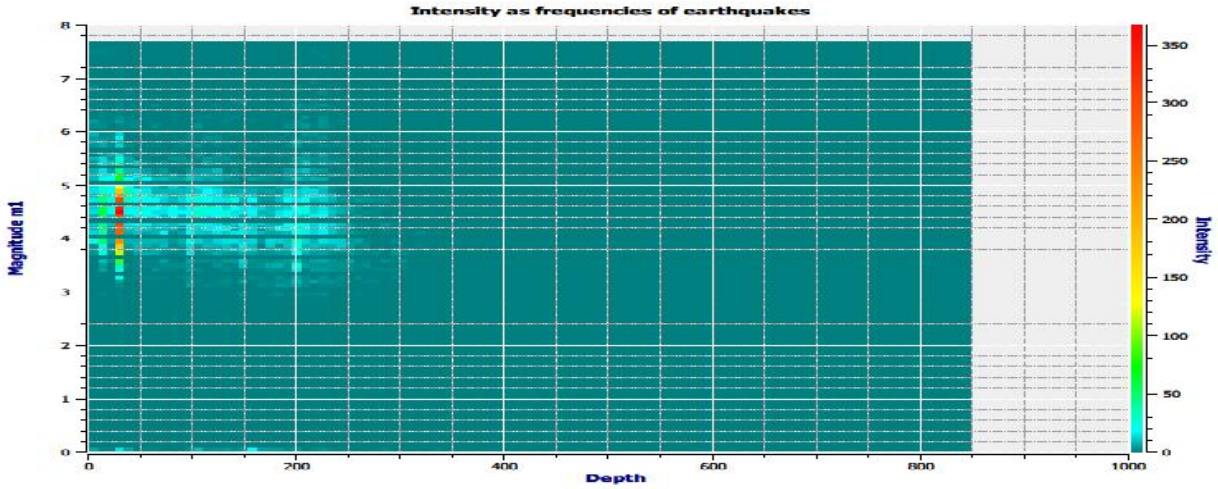


Figure 11.Showing Magnitude $m_1 = m_b$ VS Depths for Merged Catalog

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CONCLUSION

We have shown through the comparative analysis of the PMD catalog and NEIC catalog the results which are briefly summarized as follows: The catalog NEIC as compared to catalog PMD has a higher completeness level after 1986 and onwards. The catalog NEIC is essentially incomplete, within the analyzed territory, for magnitudes lower than 4.0 The catalog NEIC appears spatially complete, when compared with PMD for magnitude greater than 4.0 to 5.0 The catalog PMD and NEIC are nearly identical, during the period 1962 to 2004, for magnitudes around 4.0 to 6.0 The local catalog PMD is lacking information about time in hour: min: sec so it cannot be used for prediction purposes individually. The merged catalog is reliable for the application of different earthquake Prediction techniques from 1963 to 2007 and for seismic hazard assessment the complete merged catalog can be considered. our results shows that the merged catalog can safely be taken as reliable in studies based on catalog of earthquakes.

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