Yanbu Journal of Engineering and Science

Volume 3 | Issue 1 Article 8

2011

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Recommended Citation

Saleem, Farhana Sarwar and LalaRukh Kamal, Saleem Iqbal (2011), AN EXPRESS ANALYSIS OF A LOCAL NETWORK CATALOG OF EARTHQUAKES IN THE REGION OF QUETTA, PAKISTAN, *Yanbu Journal of Engineering and Science*: Vol. 3: Iss. 1, 76-83.
DOI: https://doi.org/10.53370/001c.24036
Available at: https://yjes.researchcommons.org/yjes/vol3/iss1/8

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Yanbu Journal
of
Engineering
and Science
ISSN: 1658-5321

Vol. 3, October 2011 (1432H)
www.yjes.org.sa

AN EXPRESS ANALYSIS OF A LOCAL NETWORK CATALOG OF EARTHQUAKES IN THE REGION OF QUETTA, PAKISTAN

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ABSTRACT

Earthquake catalogs 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. As it is well known fact that man made inhomogeneities and artifacts exist in earthquake catalogs that are produced by changing seismological networks. In this paper we are focused on the analysis of local catalog for the region Quetta, of Pakistan, as this region has a history of many large earthquakes. The local catalog considered here is referred from the International Seismological Center (ISC). The catalog contains information from 01-01-1992 to 30-06-2006. The catalog covers an area Latitude 28.00 to 32.00o N, Longitude 65.00 to 69.00o E and contains 690 events. To examine and report on the spatial and temporal homogeneity and completeness of the local catalog its comparison is done with the Global Catalog of National Earthquake Information Center (NEIC) of USA. Finally to get a homogeneous catalog for the region, we merge the two catalogs by considering different data properties and different data analysis techniques prepared by different data collection agencies. The merged catalog is rather homogeneous as variation in the completeness of the catalogs is reduced. The merged catalog is reliable for the applications of different earthquake Prediction techniques.

Keywords: *Earthquake Catalog, Frequency Magnitude Relation, Power Law.*

1. INTRODUCTION

The Quetta region has a history of the many large earthquakes and is at high seismic risk. This seismic activity is due to the movement along the active faults in the region. The Chaman fault is the main structure in this region. It is a left lateral wrench fault and is traced on the map for about 320 km along an approximate north-south orientation from latitude 27° to 30° N and extends northwards into Afghanistan for another 240 km [1]. It is the most significant tectonic feature of Pakistan, specifically in the Quetta region. The Chiltan-Takhatu faults are the other two main active thrust faults in the region. These faults pass with almost north-south orientation in the west of the Quetta Valley. There also exist some active faults and lineaments in the eastern mountains of the valley.

For complete investigation about seismicity, seismotectonic, seismic risk and hazard analysis in the region, it is essential to examine and report on the spatial and temporal homogeneity and completeness of the

Earthquake catalog. It is a common knowledge that catalogs have errors, whose identification and elimination is desirable [2]. It suffers from the three types of man-made seismicity changes identified in [3, 4, 5], 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 by Kossobokov in [6]. Systematic errors can be associated with 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 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.

2. DATA

In this paper we have considered two catalogs of earthquakes to analysis and report on the spatial and temporal homogeneity and completeness of the catalog, the local catalog prepared by Micro Seismic studies Program (MSSP) and the Global Catalog prepared by the National Earthquake Information Center Global Hypocenter data base of the US Geological Survey (USGS/NEIC GHDB).

2.1. QUETTA LOCAL CATALOG OF EARTHQUAKES

The observations made in the Quetta local catalog of earthquakes have been made by the Micro Seismic studies Program (MSSP) based in Islamabad, Pakistan. MSSP has been providing phase data to International Seismological Center (ISC) since January 1984, the objective of this cataloging has been to provide the original phase data. Although the data set reports more seismic events than NEIC GHDB, but it is lacking determination of magnitude (M_s in particular). The catalog contains information from 01-01-1992 to 30-06-2006 covering an area Latitude 28.00 to 32.00^0N, Longitude 65.00 to 69.00 ^{O}E and contains 690 events.

2.2. NATIONAL EARTHQUAKE INFORMATION CENTER GLOBAL HYPOCENTERS OF DATABASE OF THE US GEOLOGICAL SURVEY.

Earthquake catalog prepared by the National Earthquake Information Center Global Hypocenter Data base of the US Geological Survey (USGS/NEIC GHDB) is found very reliable and complete for magnitude M $\geq$ 4.0 from 1964 onward. When the World Wide Seismic Station Network (WWSSN) of USGS became operational. From the global catalog of NEIC a Sub-catalog is obtained for Quetta, Pakistan.

3. RESULTS AND DISCUSSION

In this paper we have done a comparison, data analysis and merging of two catalogs Quetta local catalog and NEIC by using computer programs like CompiCat [7], Microsoft Excel and Seismic Eruption to get a rather homogeneous catalog. The purpose of analysis and merging of the two catalogs is to extract useful information as discussed below. The comparison gives a better understanding to avoid catalog errors and uncertainties as they render invalid conclusion derived from a study based on a catalog of earthquakes. In this paper we have used different presentation techniques for analysis which includes plots of seismicity, time versus magnitude, and the Gutenberg-Richter relationship and Histograms of differences.

3.1 TIME DISTRIBUTION OF EARTHQUAKES

Earthquakes occur randomly in time. A frequency magnitude relation shows the

number of earthquakes per year and one can observe the completeness of the catalog. Fig.1 is showing the number of earthquakes per year according to the Quetta catalog. The catalog is quite complete for smaller magnitudes 3.0-4.0 but for larger magnitudes 4.5 to 6.5 the catalog is incomplete. Fig.2 shows a frequency magnitude graph from the USGS / NEIC GHDB catalog.

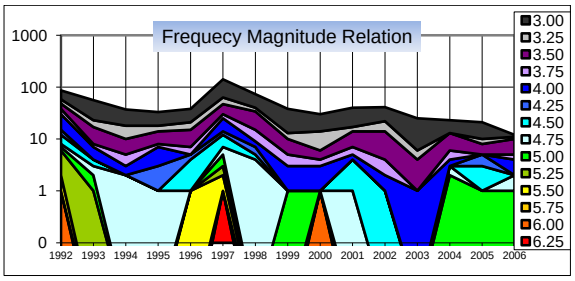

Fig.1. The number of earthquakes per year from Local catalog

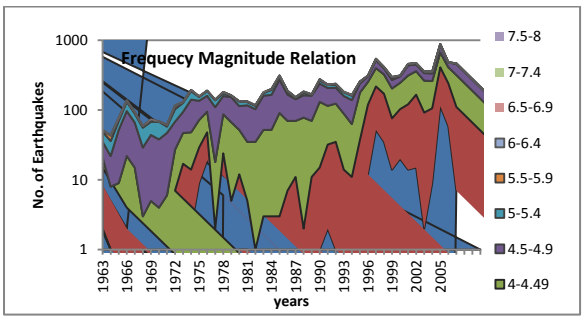

Fig.2.Frequency magnitude relation for USGS/NEIC GHDB catalog

It is obvious from Fig.2 that no record of magnitude 3.00-3.99 before 1991.Also for higher magnitudes 5.0-6.5 the catalog is not complete. For magnitudes 4.00-4.99 the catalog shows quite good completeness.

By observing the frequency magnitude relation of the two catalogs as in Fig.1 and Fig.2 we have merged the two catalogs to get a catalog with the quite good completeness of magnitude range from 3.00 to 4.99 for the region.

3.2 Difference of Hypocenter

Fig. 3 Epicenters of earthquakes reported in USGS/NEIC GHDB (left) and the Quetta Local Catalog (right). Note the evident deficiency of the aftershocks of the 1997, M 6.2 major event, as well as many small magnitude earthquakes on the right plate of the figure. The size of the dots indicates the magnitude and colour of the dots indicate the depth of the earthquake

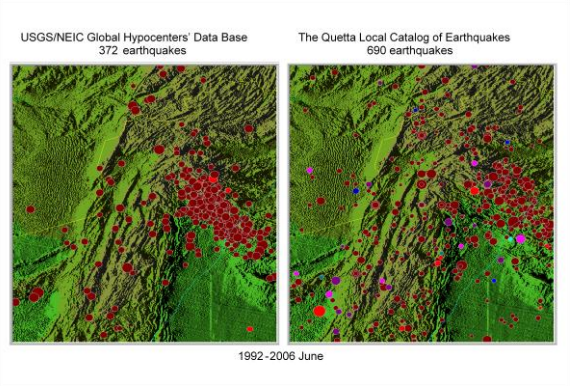

Fig. 3. Epicenters of earthquakes reported in USGS/NEIC GHDB (left) and the Quetta Local Catalog (right)

Figure3 permits making the first evident observation. On the one hand, there are many small (about magnitude 3 or larger) and a few larger (up to magnitude 5.6) events that have no match in the USGS/ NEIC GHDB. On the other hand, most of the aftershocks of the 1997 M 6.2 earthquake are absent in the local catalog. Apparently the local network was not recording at least in the first few days after this major earthquake.

3.3 Size Distribution of Earthquakes

The size distribution of earthquakes has been found to show a power law behavior. When plotted in a logarithmic plot, the distribution is linear. This was first recognized by Ishimoto and Lida [8] in Japan and Gutenberg and Richter [9], introduced the common description of the frequency of earthquakes:

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

Where N is the cumulative number of earthquakes, M is the magnitude, a and b are constants. The constant *a* reflects the absolute level of seismicity of the region and the constant *b* has been found to be consistently close to the value 1. This relationship has been found to apply to particular regions as well as to the world as a whole

.

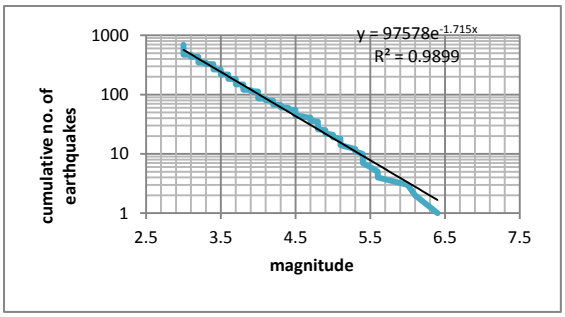

Fig. 4 The Quetta Local Catalog of earthquakes. The Gutenberg-Richter plot

As could be judged from Fig.4, a systematic, although evidently far from complete, record of earthquakes in the local catalog show up a near perfect linear plot of the Gutenberg – Richter relationship down to magnitude 3.0 (the R-squared statistic equals about 99%) while the b-slope value (b=0.7448) may indicate either an underestimation of small magnitude events or as an alternative a subcritical regime with an excess of larger magnitude events in the seismic region considered. This kind of consistency of the local catalog and reasonable completeness of the USGS/ NEIC GHDB at the magnitude level about 5 suggests combining the two data sources for a better characterization of seismic activity in the vicinity of Quetta. The combined catalog contains 1095 records from 1992 to the middle of 2006 and covers the territory between 27°N - 33°N, and 63.5°E - 70.5°E. This is the initial data source of further analysis.

3.4 Histograms of Differences

In order to perform the comparison between the two catalogs a sub catalog of the equivalent catalog records is obtained. Two records from the two 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 conditions according to [10,11]

- Time = 1 minute
- Longitude = 0.5^0
- Latitude = 0.5^0
- Depth = not limited
- Magnitude = not limited

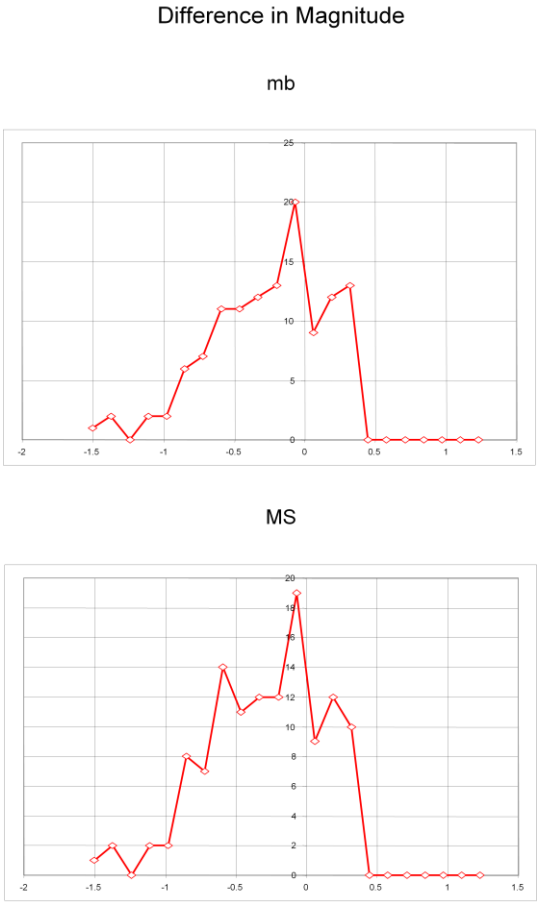

Fig. 5 Difference of magnitude between the two catalogs

Figure 5 shows a substantial difference in the magnitudes reported in the USGS/NEIC GHDB and the Quetta Local Catalog. The analysis is performed by evaluating for a fixed

type of magnitude the quantities $\Delta M = M_{Quetta} - m_b$ and $\Delta M = M_{Quetta} - M_{max}$ which are differences between magnitude of same type reported in the two catalogs for each of the common earthquake, where m_b and M_{max} is the body wave magnitude and maximum of the values reported in the USGS/NEIC GHDB for the event respectively. [In general, the USGS/NEIC GHDB may report up to the four estimations of magnitude for each single event: the average surface wave magnitude M_s and the average body wave m_b (both computed from the reported determinations from seismographic stations), along with the values of so-called authority magnitudes M_1 and M_2, which correspond to the magnitude determinations contributed by different agencies, e.g., before 1993 the surface wave magnitudes computed in Berkley and Pasadena were dominant, since 1993 these are usually the moment magnitudes from Harvard and USGS.]

The comparison of the catalogs for equivalent events shows that when the location uncertainty is set to one half of a degree, there are just 44 pairs of equivalent records present both in the global and in the local data sets. This number rises to 142 pairs, when the location uncertainty is increased to one degree. Still it is a tiny portion of the total in either of the data sets.

Figures 6, 7, 8 and 9 are showing the uncertainty in location according to the differences *of* epicenter parameters of the equivalent catalog records.These location uncertainties are caused by measurements errors and by the unfavorable geometry of stations that recorded the earthquake. The combination of both factors leads to scatter in the earthquake locations that may be quite complicated. . Uncertainties in earthquake locations can also be introduced due to errors in station parameters (location, timing), due to misidentification of seismic phases, and due to errors in the velocity model used to compute the earthquake locations. In general, these errors lead to a systematic bias in earthquake locations and, hence, they affect the accuracy of an earthquake location. If the measurement errors are known a prior, these location uncertainties can be adequately computed using modern location techniques Histograms of the differences in latitude (Fig.6), longitude (Fig.7), depth (Fig.8), and the map of epicenter misfit indicate a substantial degree of uncertainty in locating earthquakes in the vicinity of Quetta, the distributed bias in location of epicenters due to the limited area of the local network sites, in particular (Fig.9).

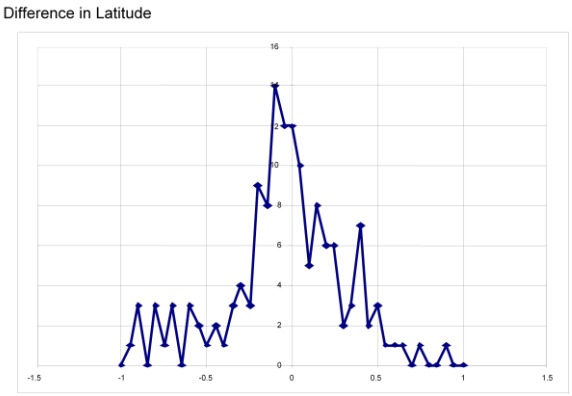

Fig.6. Showing difference in latitude for the equivalent entries of the two catalogs.

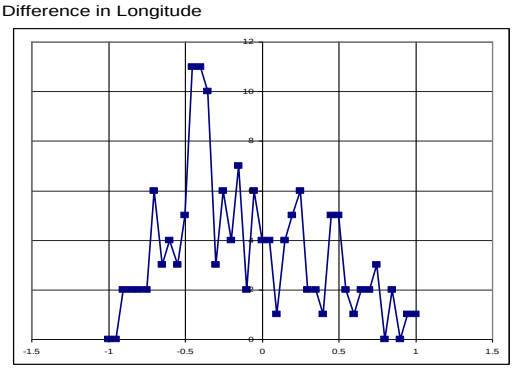

Fig.7. Showing difference in longitude for the equivalent entries of the two catalogs

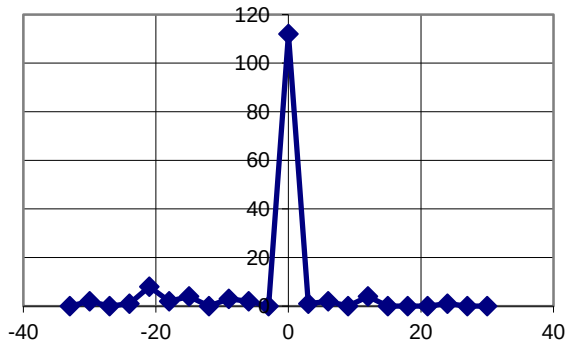

Fig. 8. Showing difference in depth for the equivalent entries of the two catalogs

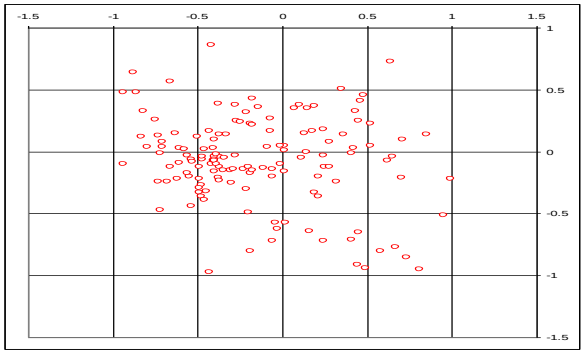

Fig. 9. This figure shows the uncertainty in location according to the difference of hypocenter parameters of the equivalent catalog record

4. CONCLUSION

The analysis of Quetta local catalog data shows that events with M 3.0 are recorded and there is no evidence of M < 3.0. The existing local catalog can be considered complete for magnitudes 3.0 – 4.0.The catalogue USGS/NEIC GHDB is essentially incomplete, within the analyzed territory, for magnitudes lower than 4.0 but for magnitudes 4-4.99 it is complete. On the basis of this kind of consistency of the local catalog as observed by the Gutenberg Richter relation and reasonable completeness of the USGS/NEIC GHDB at the magnitude level about 5 the two data sources are merged for a better characterization of seismic activity in the vicinity of Quetta. The combine catalog contains 1095 records from 1992 to the middle of 2006 and covers the territory between Latitude 27^0 N-33^0 N and Longitude 63.5^0 E-70.5^0 E. This is the initial data source for further analysis. The merged catalog is rather homogeneous as variation in the completeness of the catalogs is reduced. The merged catalog is reliable for the application of different earthquake Prediction techniques.

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تحليل دقيق لشبكة الزلازل المحلية في منطقة كوتيا في الباكستان

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قسم الرياضيات، جامعة بلوشستان، كويتا، الباكستان

الملخص:

إن كاتالوجات الزلازل تعتبر معلومات قيمه حيث تشكل أساساً لعمليات التنبؤ بخطر وقوع الزلازل. ولتحقيق ذلك فمن الضروري أن يتم إختيار مدى التجانس والتكامل الزماني والمكاني لكتالوجات الزلازل بسبب التغيرات في الشبكة الزلزالية .

في هذا البحث تم التركيز على تحليل الكتالوج المحلي للزلازل في منطقة كويتا في الباكستان حيث أن هذه المنطقة معروفة تاريخياً بتعرضها لزلازل قوية. إن هذا الكتالوج المحلي يعود إلى مركز الزلازل الدولي حيث أن هذا الكتالوج يحتوي على معلومات في الفترة من 1992/1/1 إلى 2006/6/30 وهو يغطي مناطق خط العرض 65 إلى 69 درجة شرقاً .

ولتحليل وإختيار مدى التجانس والتكامل لهذا الكتالوج الزلازالي المحلي تم مقارنته بالكتالوج الزلزالي الدولي الصادر من مركز معلومات الزلازل الوطني بالولايات المتحدة الأمريكية، وللحصول على كتالوج زلزالي متجانس للمنطقة تم دمج الكتالوجين، آخذاً بعين الإعتبار تقنيات تحليل النتائج والتي تم الحصول عليها بواسطة من وسائط مختلفة لجمع المعلومات. إن الكتالوج الناتج يعتبر متجانساً ويمكن الإعتماد عليه للتنبؤ بالزلازل..