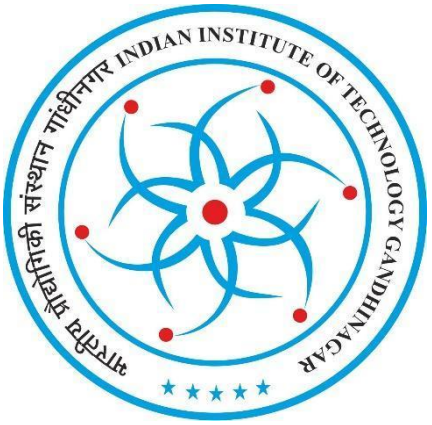
Indian Institute of Technology Gandhinagar



MBASS vs EMR for Completeness Magnitude in Indian Catalogue

MA202 Project Report

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Contents

Summary

The aim of the 'MBASS vs EMR for Completeness Magnitude in Indian catalogue' project was to compare the effectiveness of two widely used methods for determining the completeness magnitude (Mc) of earthquake catalogues in the Indian region. The two methods that were compared were the Median Based Analysis of the Segment Slope (MBASS) method and the Entire Magnitude Range (EMR) method. The Indian earthquake catalogue was used as the dataset for the project, which contains a large amount of data that can be used to assess the seismicity of the region. The MBASS method involves analyzing the slope of the frequency-magnitude distribution (FMD) of earthquakes in a catalogue to determine Mc. On the other hand, the EMR method involves comparing the observed FMD of earthquakes to the theoretical FMD expected for a complete earthquake catalogue. The results of the project showed that both the MBASS and EMR methods provided consistent and reliable Mc estimates for the Indian earthquake catalogue. The MBASS method identified Mc to be around 3.8 , while the EMR method estimated it to be between 3.4 and 3.7. The consistency between the two methods highlights the reliability of the Indian earthquake catalogue. The study provides valuable insights into the applicability of the MBASS and EMR methods for assessing Mc in other earthquake catalogues. The findings suggest that both methods can be used as complementary tools for assessing the completeness magnitude of earthquake catalogues. The results of the project have important implications for seismic hazard analysis and earthquake prediction in the Indian region. Accurate and reliable assessments of Mc are crucial for understanding the seismicity of a region and for estimating the potential maximum earthquake magnitude that could occur in the future.

Introduction

Earthquakes are a significant natural hazard that poses a serious threat to life, infrastructure, and the economy. The assessment of the completeness magnitude (Mc) of earthquake catalogues is crucial for understanding the seismicity of a region and for seismic hazard analysis. There are several methods available to determine Mc, including the Median Based Analysis of the Segment Slope (MBASS) method and the Entire Magnitude Range (EMR) method. In this project, we aim to compare the effectiveness of the MBASS and EMR methods for determining Mc in the Indian earthquake catalogue.

India is a seismically active region that experiences frequent earthquakes due to its location at the intersection of the Indian Plate and the Eurasian Plate. The Indian earthquake catalogue contains a vast amount of data that can be used to assess the seismicity of the region. However, the accuracy and completeness of the catalogue need to be evaluated to ensure reliable seismic hazard assessments.

The MBASS method involves analyzing the slope of the frequency-magnitude distribution (FMD) of earthquakes in a catalogue to determine Mc. On the other hand, the EMR method involves comparing the observed FMD of earthquakes to the theoretical FMD expected for a complete earthquake catalogue. Both methods have their advantages and limitations, and it is crucial to compare their performance in different regions and earthquake catalogues.

The EMR Method

The Entire Magnitude Range (EMR) method is a widely used approach to assess the completeness magnitude of earthquake catalogues. The completeness magnitude is the smallest magnitude of earthquakes that can be reliably detected and recorded in a given region and time period. The EMR method involves plotting the cumulative number of earthquakes versus magnitude and visually identifying a point of significant departure from a straight line. This point is known as the magnitude of completeness (Mc), and it represents the magnitude below which the earthquake catalogue is considered incomplete.

To apply the EMR method, the first step is to select the region and time period for which the completeness magnitude is to be assessed. The earthquake catalogue for the selected region and time period is then compiled from various sources, such as seismological networks, catalogues maintained by government agencies, and published literature. The cumulative number of earthquakes is then plotted against the magnitude, and the curve is visually inspected for a point of significant departure from a straight line. This point represents the completeness magnitude of the catalogue.

The completeness magnitude obtained using the EMR method should be verified using other methods, such as the magnitude of detection (Md) method, the magnitude of homogeneity (Mh) method, and the maximum curvature (Cmax) method. The Md method determines the magnitude below which a certain percentage of earthquakes are detected, while the Mh method evaluates the homogeneity of the magnitude distribution. The Cmax method identifies the maximum curvature point on the magnitude-frequency distribution curve. The completeness magnitude obtained using the EMR method should be consistent with those obtained using these other methods.

It is important to note that the EMR method is a subjective approach that relies on visual inspection of the earthquake-magnitude distribution. Therefore, the completeness magnitude obtained using this method may vary depending on the individual or team performing the analysis. To minimize this variability, multiple analysts can independently apply the EMR method and compare their results. Moreover, the completeness magnitude obtained using the EMR method should be interpreted in the context of the quality and reliability of the earthquake catalogue. catalogues with higher completeness magnitudes are generally considered to be more reliable and useful for seismic hazard assessment.

The non-cumulative FMD can be described by the intensity λ (normalized number of events) at magnitude m as:

$$\lambda(m) = \lambda_0(m)q(m)$$

$$\lambda_0(m \mid \beta) = \exp(-\beta m)$$

the G-R law, β = b log 10 and q(m) a detection function with $0 \leq q \leq 1$. q is commonly defined as the cumulative normal distribution of mean μ and standard deviation σ.

$$q(m \mid \mu, \sigma) = \int_{-\infty}^{m} \frac{1}{\sqrt{2\pi}\sigma} \exp \frac{-(x-\mu)^2}{2\sigma^2} dx$$

By substituting Eqs. 7 and 8 in Eq. 6, OK1993 provided a model to fit the FMD over the entire magnitude range. The completeness magnitude is only implicit with

$M_c(n) = \mu + n\sigma$;where n indicates the confidence level.

In conclusion, the EMR method is a widely used approach for assessing the completeness magnitude of earthquake catalogues. This method involves visually identifying the point of significant departure from a straight line in the cumulative number of earthquakes versus magnitude plot. The completeness magnitude obtained using the EMR method should be verified using other methods and interpreted in the context of the quality and reliability of the earthquake catalogue. The EMR method is subjective, and therefore, multiple analysts should independently apply the method to minimize variability.

The MBass Method

The MBASS method is a statistical approach that involves analyzing the slope of the frequency-magnitude distribution (FMD) of earthquakes in a catalogue to determine the magnitude of completeness (Mc). To apply this method, one first selects a region and time period and compiles an earthquake catalogue from various sources. The FMD of earthquakes in the catalogue is then plotted, with the earthquake magnitude on the x-axis and the logarithm of the number of earthquakes in each magnitude bin on the y-axis. The FMD is divided into several segments, each of which contains a constant slope, and the median magnitude and slope of each segment are calculated using linear regression. The point of significant change in the slope is then identified using statistical tests, such as the Bayesian Information Criterion (BIC) and the Akaike Information Criterion (AIC), which represent the Mc.

Once the Mc has been determined using the MBASS method, it can be used to assess the quality and reliability of the earthquake catalogue. In general, catalogues with higher completeness magnitudes are considered to be more reliable and useful for seismic hazard assessment. However, it is important to note that the MBASS method is a statistical approach that relies on fitting linear regression lines to segments of the FMD, and therefore, the completeness magnitude obtained using this method may depend on the number and size of the segments chosen. To minimize this variability, multiple segmentations can be performed, and the results can be compared.

It is also important to verify the completeness magnitude obtained using the MBASS method using other methods, such as the Entire Magnitude Range (EMR) method and the magnitude of detection (Md) method. The EMR method involves comparing the observed FMD of earthquakes to the theoretical FMD expected for a complete earthquake catalogue, while the Md method involves analyzing the detection threshold of the seismic network used to compile the earthquake catalogue. The completeness magnitude obtained using the MBASS method should be consistent with the completeness magnitude obtained using these other methods.

In conclusion, the MBASS method is a statistical approach for assessing the completeness magnitude of earthquake catalogues. This method involves analyzing the slope of the FMD of earthquakes in the catalogue, dividing the FMD into segments, and identifying the point of significant change in the slope as the Mc. The Mc obtained using the MBASS method should be interpreted in the context of the quality and reliability of the earthquake catalogue and verified using other methods. To minimize variability, multiple segmentations can be performed.

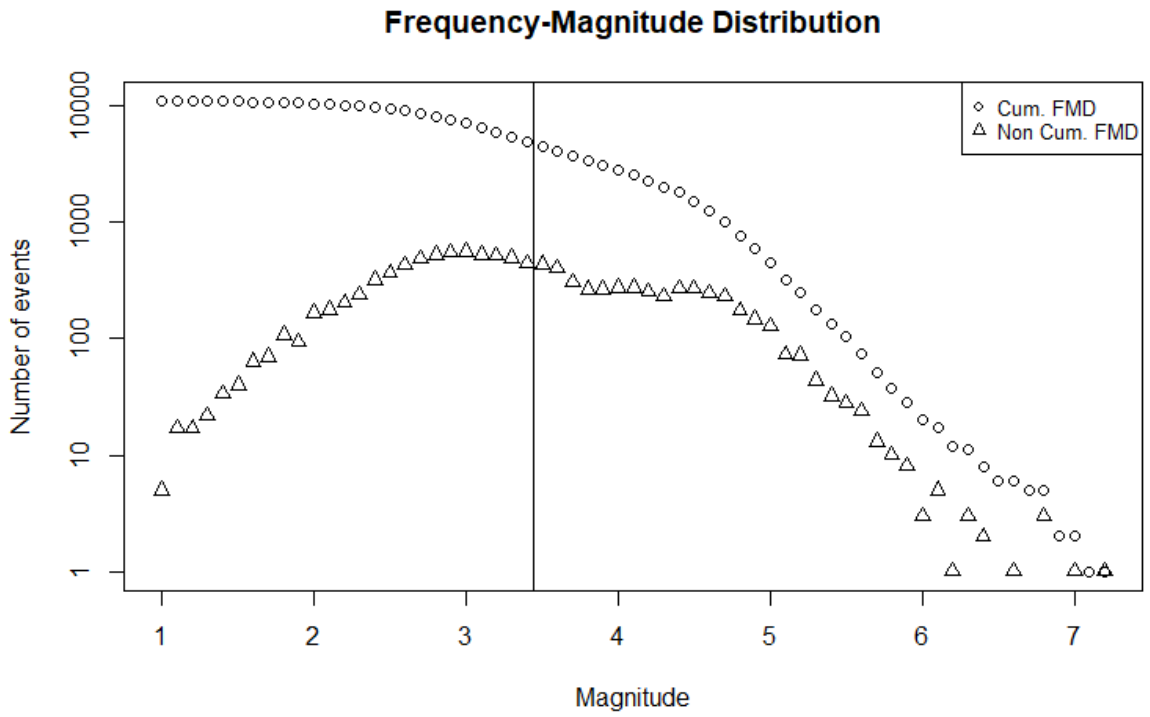
Implementing EMR Method

We will calculate Completeness magnitude from the EMR method. The Algorithm for EMR method that we used is provided in this link.

Dataset 1

sample size	Mc mean	standard deviation
200 sample	3.4425	0.09157334979

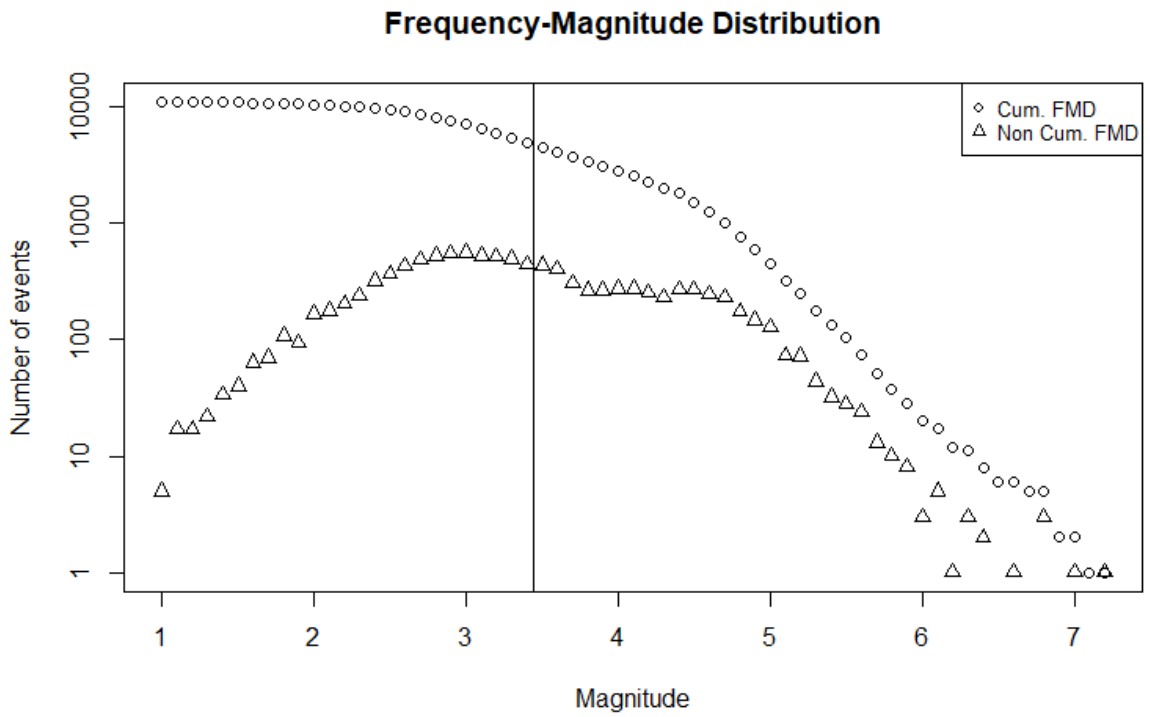
Plot



Dataset 2

sample size	Mc mean	standard deviation
1000 sample	3.446	0.08889632079

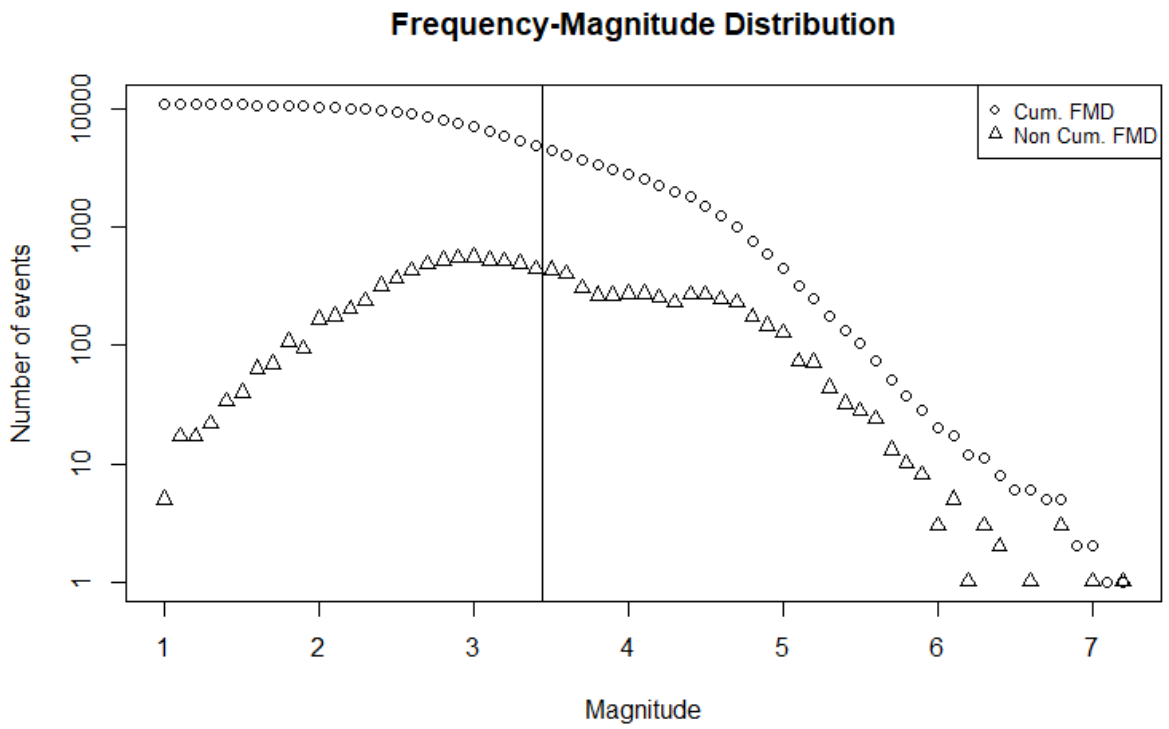
Plot



Dataset 3

sample size	Mc mean	standard deviation
5000 sample	3.44274	0.09013832361

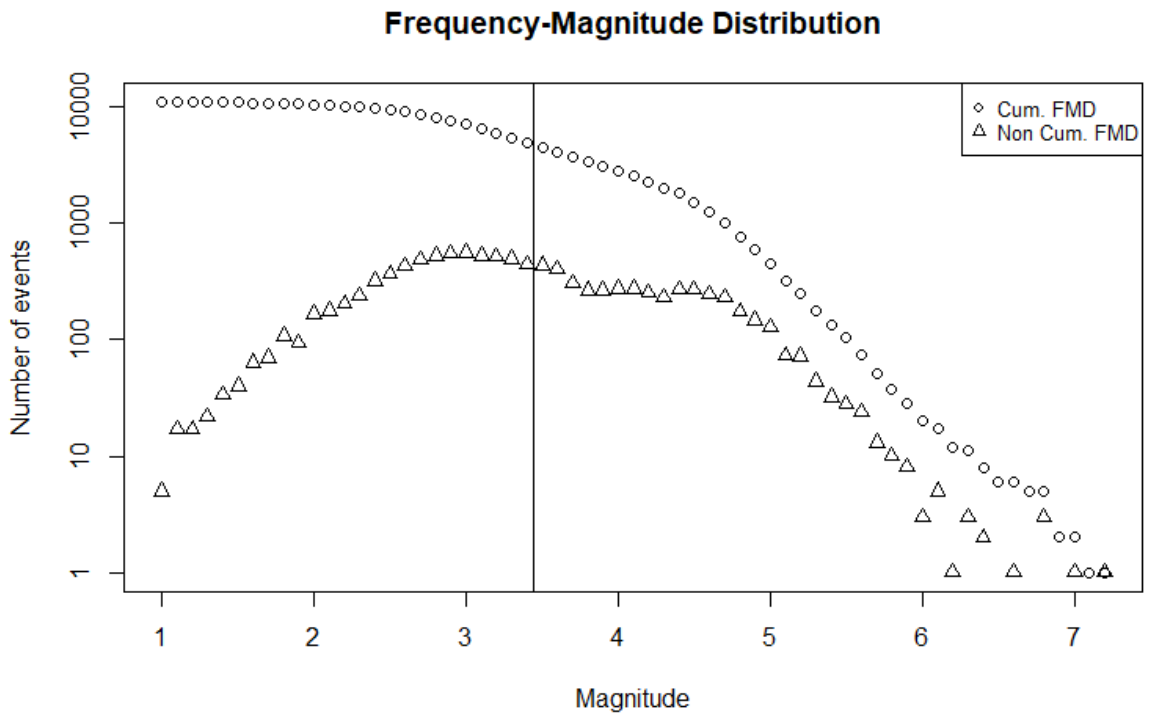
Plot



Dataset 4

sample size	Mc mean	standard deviation
11000 sample	3.441609091	0.09018851623

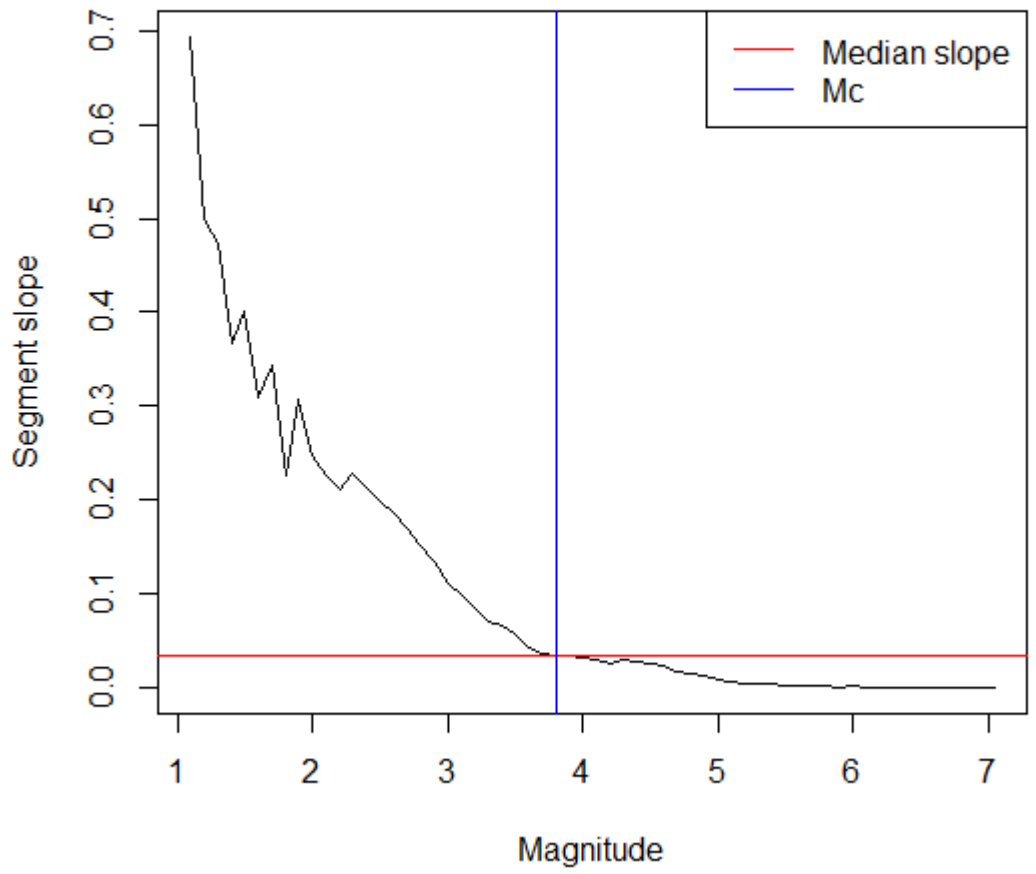
Plot


Frequency-Magnitude Distribution
Cum. FMD
Non Cum. FMD
Number of events
10000
1000
100
10
1
1
2
3
4
5
6
7
Magnitude

Implementing the Median-Based Analysis of the Segment Slope (MBASS) Method

We will calculate Completeness magnitude from the MBASS method. The Algorithm that we used for the MBASS method is provided in this link.

Plot



Mc value = 3.8

Comparing the MBass and the EMR methods

Both the MBASS and EMR techniques are used to assess the completeness magnitude of earthquake catalogues, although they do so in distinct ways.

The MBASS approach is based on an examination of the median slope of the magnitude-frequency distribution (MFD) in a specified catalogue section. The magnitude of completeness is defined as the magnitude at which the slope of the MFD deviates considerably from its original value. The approach has been demonstrated to be useful in assessing completeness magnitude in a variety of earthquake catalogues, including those from India.

Many studies have demonstrated that when comparing MBASS and EMR for completeness magnitude estimation in the Indian earthquake catalogue, both approaches may produce respectable estimations of completeness magnitude. The MBASS technique, on the other hand, has been found to be more resilient and less subject to slight variations in the MFD, whereas the EMR method can be impacted by event catalogue uncertainties and may be less trustworthy in catalogues with insufficient data.

Generally, the technique of choosing is determined by the features of the earthquake catalogue and the research topic at hand. When assessing the completeness magnitude estimates, it may be interesting to compare the findings produced using both approaches and to examine their different strengths and limits.

Based on an examination of the median slope of the magnitude-frequency distribution (MFD) in a given segment of the earthquake catalogue, the MBASS approach determines the completeness magnitude. The MFD is a histogram that depicts the distribution of earthquake magnitudes in the catalogue, with magnitude bins on the x-axis and the number of earthquakes in each bin on the y-axis. The MBASS approach chooses a segment of the MFD where the distribution is thought to be well-behaved, often in the magnitude range below the catalogue's greatest magnitude. The algorithm then computes the median slope of the MFD in this segment, and the completeness magnitude is defined as the magnitude at which the slope deviates considerably from its original value.

By fitting a linear regression line to the cumulative number of occurrences versus magnitude distribution, the EMR approach predicts the completeness magnitude. The cumulative distribution plots the total number of earthquakes in the catalogue that have a magnitude higher than or equal to a specific magnitude. The regression line is fitted to the linear section of the cumulative distribution, and the magnitude of completeness is defined as the magnitude at which the line's slope deviates considerably from unity.

While both techniques may yield respectable estimates of completeness magnitude in earthquake catalogues, the MBASS method has been demonstrated to be more resilient and less subject to modest MFD variations. This is due to the method's use of the MFD's median

slope, which is less impacted by outliers and tiny fluctuations in the distribution than the mean slope utilised in other approaches. Furthermore, the MBASS approach may be used to regions of the MFD where the distribution is well-behaved, which can assist to mitigate the influence of data errors and seismicity rate changes.

The EMR technique, on the other hand, may be less accurate in catalogues with little data, where the linear part of the cumulative distribution may be poorly characterized. Moreover, errors in the event catalogue, such as insufficient or erroneous magnitudes or location information, may have an impact on the technique.

Generally, the technique of choosing is determined by the features of the earthquake catalogue and the research topic at hand. When assessing the completeness magnitude estimates, it may be interesting to compare the findings produced using both approaches and to examine their different strengths and limits.

Conclusion

Estimating the completeness magnitude is an important aspect of earthquake catalogue analysis as it helps to identify the level of completeness of the catalogue and the potential biases in the seismicity data. The completeness magnitude is the magnitude below which earthquakes are likely to be missed due to instrumental or other limitations.

Two commonly used methods for estimating the completeness magnitude in earthquake catalogues are the Median-Based Analysis of the Segment Slope (MBASS) and the Event-Magnitude Relation (EMR). Both methods have been applied to the Indian earthquake catalogue and have been shown to provide reasonable estimates of completeness magnitude.

The MBASS method is based on the analysis of the median slope of the magnitude-frequency distribution (MFD) in a specific segment of the catalogue. This method has been shown to be more robust and less sensitive to small fluctuations in the MFD. Additionally, the method can be applied to segments of the MFD where the distribution is well-behaved, which can help to reduce the impact of data uncertainties and variations in the seismicity rate.

The EMR method, on the other hand, estimates the completeness magnitude by fitting a linear regression line to the cumulative number of events versus magnitude distribution. This method may be less reliable in catalogues with limited data, where the linear portion of the cumulative distribution may not be well-defined. Additionally, the method may be affected by uncertainties in the event catalogue, such as incomplete or inaccurate magnitudes or location information.

Therefore, when choosing between MBASS and EMR for completeness magnitude estimation in the Indian earthquake catalogue, researchers should consider the specific characteristics of the catalogue and the research question at hand. It may be useful to compare the results obtained using both methods and to consider their respective strengths and limitations when interpreting the completeness magnitude estimates.

In conclusion, both the MBASS and EMR approaches are suitable for measuring the completeness magnitude in earthquake catalogues. However, the strategy chosen is determined by the catalogue's individual qualities and the research topic at hand. Researchers can acquire more reliable estimates of completeness magnitude and enhance the accuracy of earthquake catalogue studies by carefully analysing the strengths and limits of each technique.

References

[1]*Amorese, Daniel. (2007). Amorèse D., 2007, Applying a Change-Point Detection Method on Frequency-Magnitude Distributions, Bull. Seism. Soc. Am. 97, no 5, 1742-1749.. Bulletin of the Seismological Society of America. 97. 1742-1749. 10.1785/0120060181.*

[2]*Mignan, A. & Woessner, Jochen. (2012). Estimating the magnitude of completeness for earthquake catalogues. Community Online Resource for Statistical Seismicity Analysis. 10.5078/corsa-00180805.*