SITE RESPONSE ANALYSIS FOR ASSAM AND MEGHALAYA

A dissertation
Submitted in the partial fulfillment of the requirement for the award of the degree of MASTER OF TECHNOLOGY
In
CIVIL ENGINEERING
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DECLARATION

I hereby declare that the work presented in the dissertation **"SITE RESPONSE ANALYSIS FOR ASSAM AND MEGHALAYA"** in partial fulfillment of the requirement for the award of the degree of "MASTER OF TECHNOLOGY" in Civil Engineering (with specialization in Geotechnical Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati-13 under Assam Science & Technology University, is a real record of my work carried out in the said college for six months under the supervision of Dr. Sasanka Borah, Associate Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati -13.

Whatever I have presented in this report has not been submitted by me for the award of any other Degree or Diploma.

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ABSTRACT

North-East India is prone to frequent earthquakes ranging from small to large, so as a preliminary hazard assessment for the region of Assam and around it, an attempt has been made to study the ground response of specific locations. To study the predominant frequencies and amplification of the site and its response Fourier Spectral Ratio in the form of HVSR (Horizontal-Vertical Spectral Ratio) and SSR (Standard Spectral Ratio) was carried out for seismic records of each station. Analysis and comparison between the predominant frequencies and site amplification seen from all three methods and the advantages and disadvantages of one over the other were attempted. It was found that the range of frequency depends on several parameters and factors. Similarly, the site amplification factor viz. the local site effect depends on the class of soil viz. site classification, seismic intensity, and the topography of the region. The predominant frequency range and site amplification factor helps for designing of structure.

And also the how different magnitudes of strong-motion influences a particular site or region; effect of low intensity earthquake with respect to high intensity earthquake, prominent peaks can be observed from higher intensity earthquakes, thus while determining the predominant frequency of a particular site or region suitable seismic records get better accuracy results.

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1 INTRODUCTION

1.1 General

The North-Eastern Region (NER) i.e. Assam and Meghalaya are prone to earthquakes due to the active faults formed as a result of the collision of the Indian Tectonic Plate with the Eurasian Tectonic Plate, which led to the formation of the Himalayas. These regions are classified as seismic zone IV-V, which makes seismic hazard analysis crucial for preliminary assessment. Assam falls under Seismic Zone V, which is the highest-risk seismic zone in India. This classification indicates that the region is highly prone to earthquakes due to tectonic activity associated with the Himalayan and Indo-Burmese tectonic plates. Assam, along with other parts of northeastern India, experiences frequent seismic activity and has a history of significant earthquakes, including the Great Assam Earthquake of 1950, one of the most powerful earthquakes recorded. Meghalaya is categorized under Seismic Zone V in India, which is the highest-risk zone for earthquakes. This designation means that Meghalaya is highly vulnerable to seismic activity, with a likelihood of experiencing strong and potentially damaging earthquakes. The categorization is part of India's seismic zoning map, which divides regions based on earthquake risk levels from Zone II (low risk) to Zone V (very high risk). It is important to note that the intensity of an earthquake can differ among regions, and the tremor felt in one area may differ from another due to the local site effect. The local site effect is mainly determined by the class of soil, seismic intensity, and topography of the region. Generally, soil experiences greater site amplification than rock during an earthquake.

A study was conducted to identify the predominant frequencies and site amplification of North Eastern Regions to get an overview of the seismic hazard. The goal of this study was to better understand the characteristics of earthquakes in these regions and to inform the design of structures and buildings to withstand seismic activity. This knowledge is essential for protecting the lives and livelihoods of the people living in these regions and avoiding damage to the infrastructure and properties.

The Horizontal-Vertical Spectral Ratio (HVSR) using the Nakamura Method, reported by Nakamura Y. (1989), is a widely used and accepted method for estimating the predominant frequency and site amplification factor of the surface layer. This method calculates the spectral ratio (commonly denoted as WV Ratio) by dividing the Fourier spectrum of the horizontal component by the Fourier spectrum of the vertical component of seismic or earthquake records.

Another method for evaluating the predominant frequency and site amplification is the Standard Spectral Ratio (SSR) Method by Mittal H. et.al. (2013). The SSR method is defined as the Spectral ratio of the Fourier spectrum of seismic or earthquake records of a particular site, Compared to that of a nearby rock site from the same seismic activity or earthquake and the same component. For example, if two site stations were triggered, SITE A and SITE B, during a particular earthquake, with EW, NS, and VT as the East-West, North-South, and Vertical Components respectively, and assuming SITE A to be a soil site and SITE B a rock site, the SSR for SITE A concerning SITE B for a particular component, say East-West (EW) component, would be given by the ratio of Fourier spectrum of SITE A-EW and Fourier spectrum of SITE B-EW .Comparing all three methods for estimating the predominant frequencies and site amplification will give a brief overview of the frequency range and its accuracy, as well as the limitations of each method over the others. It is important to consider these different methods and their strengths and weaknesses to choose the most appropriate method for a specific situation, and to understand the uncertainty associated with the estimates obtained from each method.

In addition to the analysis of the predominant frequency and site amplification, the influence of magnitude, also known as strong-motion data, was also studied for a few sites in the city of Guwahati. The study was conducted by comparing the response of a particular site to earthquakes of different magnitudes. For example, the site response was computed for different magnitudes of earthquakes and the predominant frequency and site response were noted for each magnitude.

This analysis of the influence of strong-motion data allows for the comparison of the effects of earthquakes of different magnitudes on a specific site. By understanding how different magnitudes of earthquakes may impact a site, it is possible to get an idea of the consequences of earthquake devastation caused by different magnitudes. This information is important for understanding the level of risk associated with building in a certain area and can inform decisions about whether or not to build in a certain location, or what kind of building design is needed to make sure it can withstand earthquake shaking of different magnitudes. Overall, this analysis is crucial for minimizing damage and ensuring safety for the people living in Guwahati city during earthquakes.

1.2 PESMOS

PESMOS which stands for Program for Excellence in Strong Motion Studies is a part of the Department of Earthquake Engineering established at the University of Roorkee (Now Indian Institute of Technology, Roorkee) in 1960. It deals with earthquake engineering problems and challenges. Its main motive is to bring together structural and geotechnical engineers, geologists, and seismologists working as a team under one roof. PESMOS is fully interdisciplinary since its induction and happens to be only one of its kinds in India.

1.3 COSMOS

Consortium of Organizations for Strong Motion Observation System (COSMOS) was established in 1997 which promotes improving strong-motion measurements, solving mutual problems with instrumentation and data, and assisting in strong-motion data dissemination with collaboration of programs and institutions. Its huge library of strong ground motion data recorded anywhere in the world are available in its Virtual Data Centre (VDC).

1.4 Area of Study

India is divided into 4 seismic zones, ranging from Il to V, with Assam (North-Eastern region) and Meghalaya being the most at risk for seismic activity as it falls under the highest vulnerability category, zone V. The NER has a history of large-scale earthquakes, with notable examples being the 12 June 1897 Assam Earthquake and the 15 August 1950 Assam Earthquake. As the region continues to experience economic growth, there has also been an increase in vertical development.

In this study, earthquake data records (time history data) were collected from the COSMOS (Consortium of Organizations for Strong Motion Observation System) database for worldwide earthquake data, of which selected recording stations are shown in figure 1.1 and mentioned in Table I .2 and PESMOS (Program for Excellence in Strong Motion Studies), 11T Roorkee, India, of which the selected PESMOS station are shown in figure 1.2. and mentioned in Table 1.1 of Appendix-I. And borehole data has been collected from the "Seismic Micro zonation Atlas of Guwahati Region, Department of Science & Technology (2007)". Missing data were filled and cross-checked from the USGS (United States Geological Survey) and IMD (Indian Metrological Department). MATLAB 2020b (Student Version) was used for data processing and analysis of earthquake records (time history data) for Horizontal-Vertical Spectral Ratio (HVSR) and Standard Spectral Ratio (SSR), DEEPSOIL v6.l was used for I-Dimensional Equivalent linear Site Response Analysis Method. For mapping the stations and earthquakes QGIS was helpful. A list of stations and a list of earthquakes are mentioned in Appendix I

Adding to Assam of India, the highest recorded earthquake in Meghalaya occurred on June 12, 1897. Known as the Great Assam Earthquake, it had a magnitude of 8.1 on the Richter scale and caused extensive damage across the northeastern region of India, including Meghalaya. The earthquake originated near the Shillong Plateau and affected Assam, Meghalaya, and parts of Bangladesh, resulting in significant loss of life and property.

1.5 Objective

The goal of the study is to understand how soil behaves during seismic activity in Assam and Meghalaya using available data. The estimation of the Predominant frequency and Site amplification factor are crucial parameters for this study. The Predominant frequency is the period of the highest amplitude of the main component of motion and has the highest potential for causing damage, making it a significant characteristic of a site's dynamics. The Site amplification is determined by factors such as the composition of soil layers, Shear wave velocities, thickness of each layer, and properties of the layers.

2. LITERATURE REVIEW

2.1 Introduction

Site Response Analysis by different methods with recent developments in the field was performed by different research workers using several platforms. Researchers from all around the world tried to present a relationship between Fourier Amplitude and Input-Energy Spectra. Single-degree-of-freedom (SDOF) and Multiple-degree-of-freedom (MDOF) both methods were being approaches researchers. A brief discussion about research works is discussed in this section.

Review of Literature

Site Response Analysis like Horizontal-Vertical Spectral Ratio (HVSR); Standard Spectral Ratio (SSR) Method and I -Dimensional Equivalent Linear Site Response Analysis Method was presented by Borah S., Pathak J. and Goswami D. (2016); Kumar S.S., and Krishna A.M.(2012), Nakamura Y. (1989), (2008) and (2011).

Nakamura Y. (2008), presented the H/V spectral ratio found from strong motions motion at various sites in Japan. Usually, on soft ground, the horizontal motion is larger than the vertical motion whereas on hard ground or rock, the difference becomes insignificant. The horizontal Vertical ratio was derived and compared with soft ground to estimate the amplification factor. Thus, horizontal to vertical ratio corresponds to ground characteristics. Moreover, the predominant frequency can also be estimated by the horizontal-to-vertical of micro tremors.

Kumar S.S. and Krishna A.M., (2012), in their work they showed the amplifying behavior of soil sites by performing I -Dimensional Equivalent Linear Site Response Analysis in Guwahati City. They collected soil strata data from various construction sites, viz borehole data from Ahomgaon, Amingaon, Beltola, and Bhangagarh. They used four strong ground motions recorded during different earthquakes in the region. Fourier Amplitude Ratio (FAR) of ground motion was in the range of (7.15 — 11.78) with a fundamental frequency range of (2.9 4.14) Hz.

Borah S., Goswami D., and Pathak J., (2016) in their research they tried to study the ground response in the Western part of Guwahati city on the South bank side of the Brahmaputra River. Estimation of amplification parameters in the region based on SPT borehole investigation data. Spectral Ratio Analysis of Horizontal-Vertical Spectral Ratio (HVSR) and Standard Spectral Ratio (SSR) was performed along with I-Dimensional Equivalent Linear Site Response Analysis, and a general comparison was made for amplification factor and predominant frequency. It indicated that field ground motion is greatly influenced by the presence of soft alluvium in the region. Again, in other research work by Borah S., Goswami D., and Pathak J., (2016), they attempted to study site response for sustainable urban planning in the western Guwahati region. Here, they studied the site-specific site amplification in the Western Guwahati region for urban development considering regional seismicity and various constructional activities in the region. (Mario Ordaz et al) in his paper he tried to present an exact theoretical relation between the Fourier Amplitude and the elastic input-energy spectrum. In his work, he computed the energy spectrum from the Fourier acceleration amplitude spectrum and the real part of the relative velocity transfer function of the single-degree-of-freedom elastic oscillator. From his work we can, understand and have scope for further studies of the relationship between the energy spectrum and other seismological variables such as magnitude and focal distance.

For the computation of Energy (Undamped Energy):
He observed that energy the spectrum is independent of accelerogram phases, and variables required for computation can be derived from amplitude Fourier spectrum.
In the paper presented by (Hitoshi Kuwamura et al), the energy spectra of damped SDOF systems and undamped MDOF systems caused by a strong motion his case earthquake) can be predicted by smoothening the Fourier amplitude spectrum of the base acceleration.
Earlier Akiyama showed that the basis of numerous response analyses tis hat earthquake energy input to a structure is governed primarily by the natural period and total mass of the structure.

3. METHODOLOGY

3.1 Introduction

With the available data collected from PESMOS (Program for Excellence in Strong Motion Studies); COSMOS (Consortium of Organizations for Strong Motion Observation System); USGS (United States Geological Survey) and IMD (Indian Metrological Department) analyses were done for Horizontal-Vertical Spectral Ratio (HV SR) Method, Standard Spectral Ratio (SSR) Method and I-Dimensional Equivalent Linear Site Response Analysis Method for the estimation of predominant frequency and site amplification of PESMOS and COSMOS stations.
MATLAB and DEEPSOIL and SEISMOSIGNAL were extensively used for all the analyses.

3.2 Site Response Analysis

Earthquake at the source is different compared to its nearby region, thus the shaking may have different values based on different elements and also it will vary from place to place based on distance, surface material, and other factors.
Different methods and approaches are being presented with satisfactory to appreciable outcomes for the study of site response analysis.
Nowadays, Moment magnitude is most commonly used to determine the san of an earthquake, however, there is another way of measuring the size of an earthquake by determining the energy released during the earthquake. It is the energy radiated that

have potential to cause damage to structures. An earthquake releases energy at many frequencies, all the frequencies are included to compute the energy released; but only frequencies or a range of frequency have the potential to create havoc or have substantial energy to create destruction to the structures. Usually, the total energy released by each whole number increase in magnitude is 32 times more energy (considering all the energies during the event).For example; an earthquake of magnitude 5 has 32 times more energy than an earthquake of magnitude 4. A relation to approximately estimate the Energy Magnitude is given by

$$\textbf{Log } M_{e}=5.24 + 1.44\, M_{w} \textbf{ (Eq 11)}$$

Where, M_e is Energy Magnitude and M_w is Moment Magnitude.

But On ground level the energy dissipates and only a fraction remains as kinetic energy.

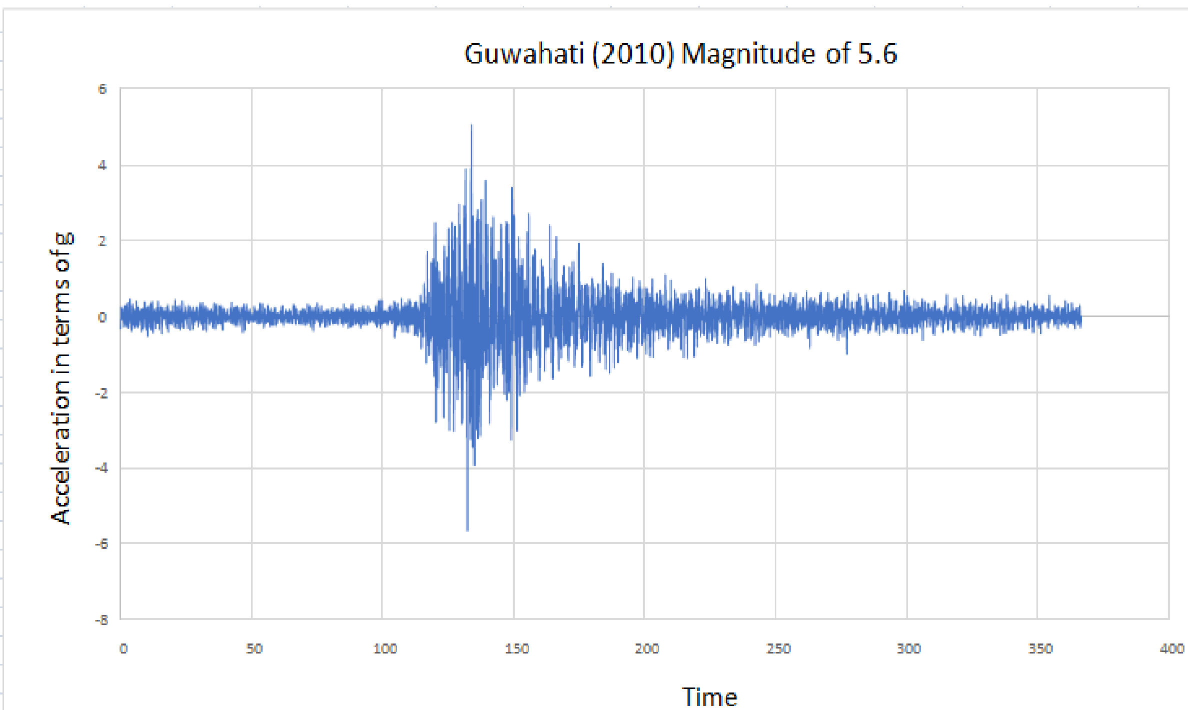


Figure 3.1: Acceleration vs. Time Plot of a seismic record

3.2.1 Fourier Amplitude Spectra

The seismic records (time history data) (reference figure 3.1) collected were transformed into Fourier Spectra using Fast-Fourier Transform (FFT) of the frequency domain. Fourier Amplitude Smoothening was done using the Gaussian filter of MATLAB, typical Fourier amplitude vs. frequency plot can be seen in figure 3.2. And we considered the frequency range of (0.1 — 10) Hz, as super tall structures are usually not constructed over this region.

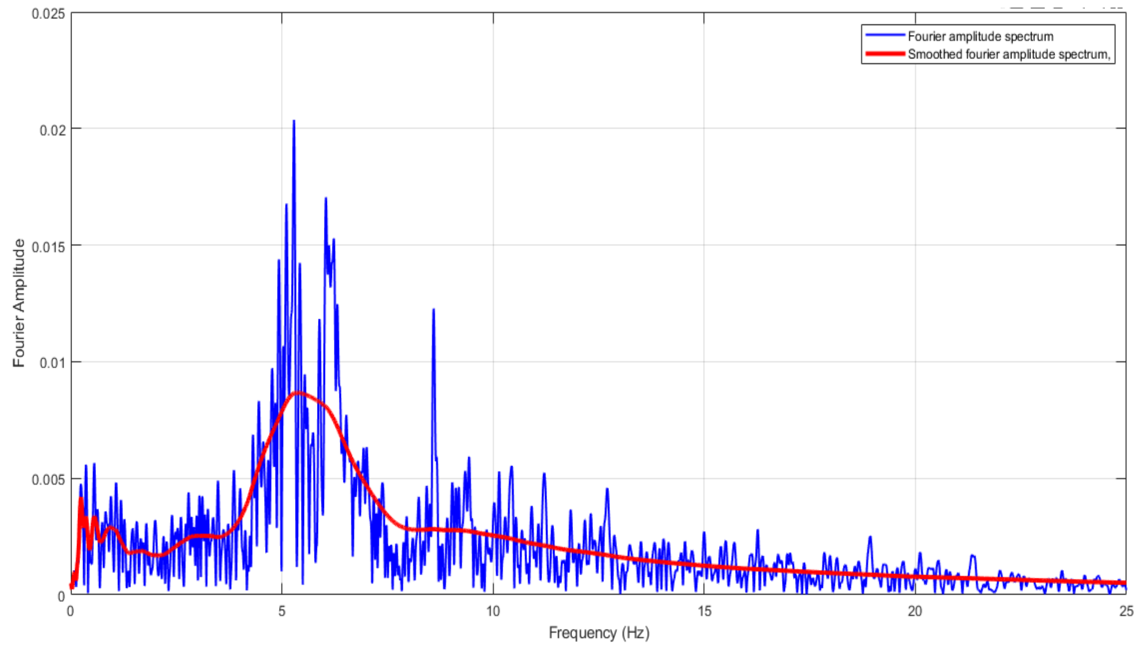


Figure 3.2: Fourier Amplitude vs. Frequency Plot of a seismic record

3.3 Horizontal-Vertical Spectral Ratio (HVSR) Method

The term of horizontal to vertical spectral ratio (HVSR) has been in seismology for long, as it used to evaluate the frequency content of ground motion during the earthquakes or any other seismic activities. It is the measure of ratio of the spectral acceleration in the horizontal direction (taken one direction at a time) to the spectral acceleration in the vertical direction at a given frequency. HVSR is typically evaluated from the strong-motion data collected from accelerometer from recording station during an earthquake or any other seismic activity.

During the 1970s the first use of HVSR was recorded, it was used for the evaluation of response of structure to ground motion during earthquakes. Further developed and refined for more efficient and accurate results.

The use of the HVSR has become more widespread in recent years as advances in technology made it easier to collect and analyze strong-motion acceleration data. Today, the HVSR is widely used in seismology and engineering, in our case geotechnical engineering and earthquake engineering to evaluate the response of structures and soils to ground motion during earthquakes, and to classify soil types based on their frequency response characteristics.

Several ways in which the horizontal to vertical spectral ratio (HVSR) can be evaluated:

- Frequency of maximum value
- Ratio of mean values
- Ratio of integral values
- Ratio of peak values
- Visual Inspection

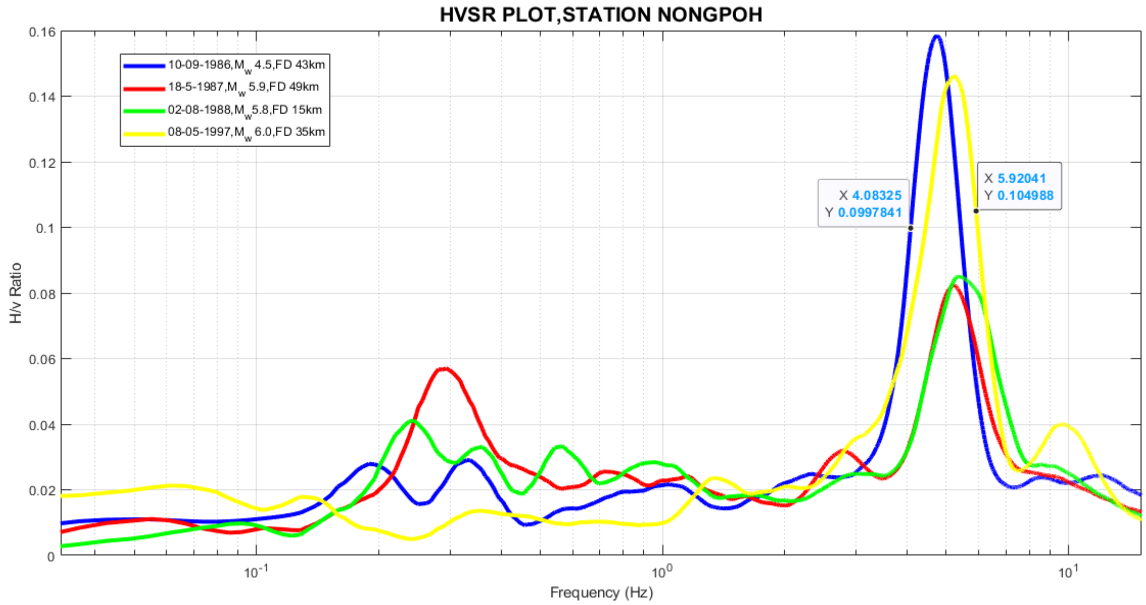
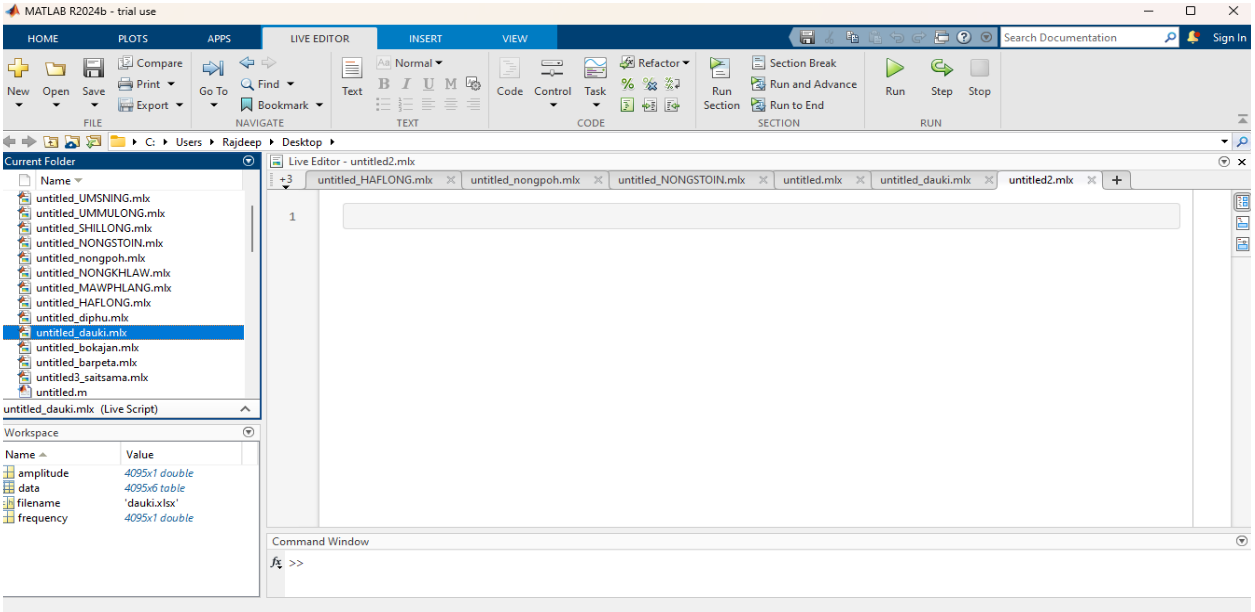


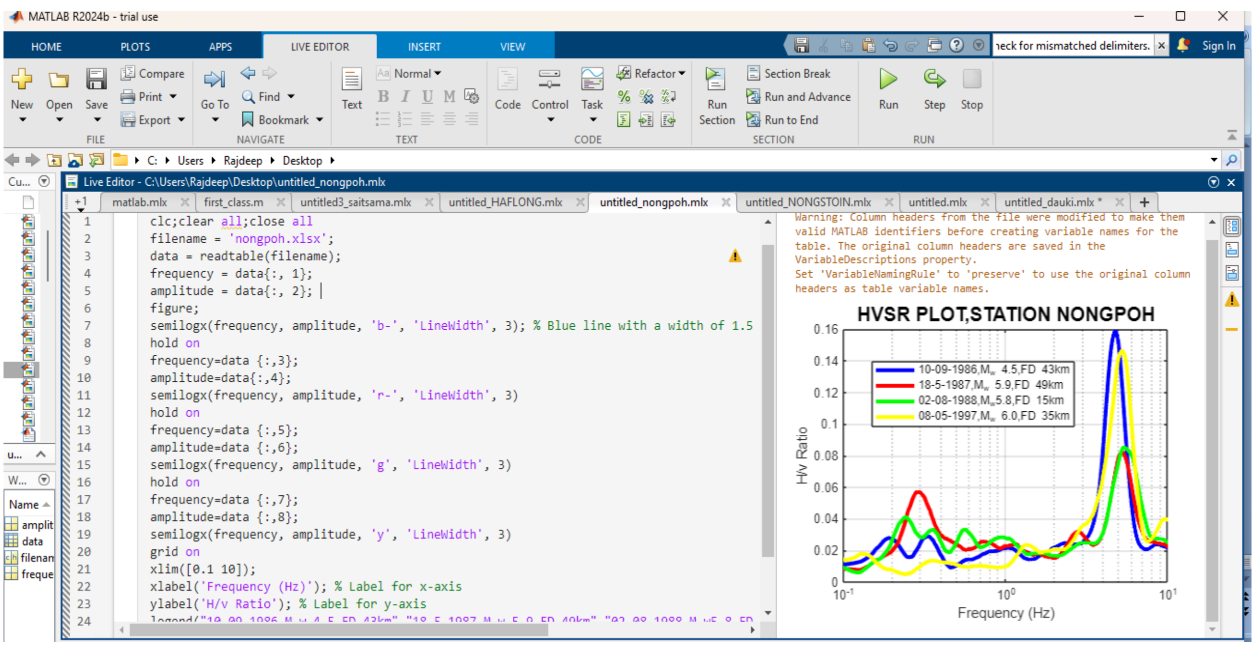
Figure 3.3: Predominant Frequency Range of a HVSR Plot

HVSR, also known as Horizontal to Vertical Spectral Ratio, is a method for determining the seismic behavior of an area by measuring the proportion of horizontal and vertical vibrations at a certain frequency, usually between 0.1-10 Hz. The peak of the graph of the HV SR plotted against frequency is used to identify the fundamental frequency of the location, which can be used to infer information about the subsurface structure and soil properties. This method is commonly used in evaluating potential hazards and characterizing sites. The most famous and widespread technique of evaluation of HVSR is the Nakamura Technique which was developed by T. Nakamura in the 1990s for seismic hazard assessment.

3.3.1 Nakamura Technique

This technique for estimation of horizontal-to-vertical spectral ratio (HVSR) of ground motions, particularly used in geotechnical and earthquake engineering. It is done by analyzing the frequency content of ground acceleration data recorded during an earthquake and calculating the HVSR as the ratio of the horizontal spectral acceleration to the vertical spectral. Each processed spectrum was used for the calculation of spectral ratio, in these cases, Horizontal-Vertical Spectral Ratio (HVSR), is the ratio between Fourier spectra of a seismic component to Fourier spectra of a vertical seismic component for the same earthquake. Figure 3.3.1.2 represents the output of the method. Similarly, Spectral Ratio for both the components was carried out East-West (EW) and PESMOS stations and Lateral (L) and Transverse (T) -COSMOS stations against vertical components.





HVSR Codes with results in MATLAB 2024b

4. ANALYSIS AND RESULTS

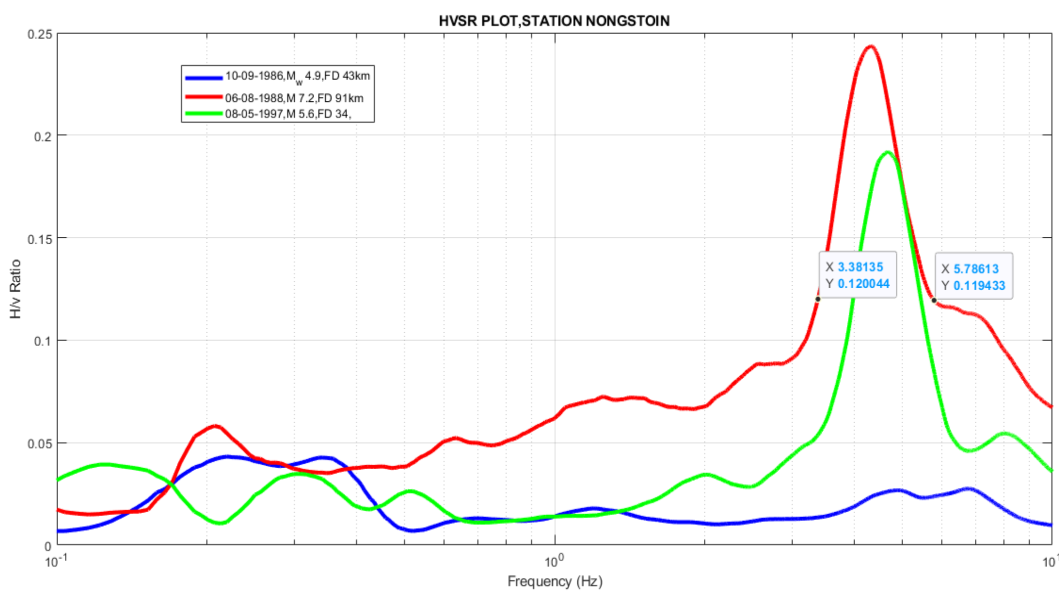
4.1 Introduction

This chapter deals with the formulation and analysis of the different site response analysis methods used. Every data is being presented in the form of graphs and plot.

4.2 Horizontal-Vertical Spectral Ratio (HVSR) Method

Horizontal-Vertical Spectral Ratio (HVSR) of East-West (EW) analysed for a few sites and the dominant frequency range was observed as of

- In Nongstoin, a rock site, its predominant frequency was in the range of (3.381 - 5.78) Hz
- In Diphu, a dense soil site, its predominant frequency ranges from (2.14-5.16)Hz
- In Barpeta ,a stiff soil site ,its predominant frequency ranges from(0.81-1.41)Hz



Few sites show different characteristics, they exhibit two peaks of predominant frequency like in Kokrajhar, soft-soil site; it ranges from (0.40- 0.90) Hz and (1.75-2.90) Hz for East-West (EW) component

5. CONCLUSION

The following conclusions have been reached within the scope of the study:

The analysis for site response aimed at identifying the possible predominant frequency and in order to minimize or avoid damages or failures caused by earthquakes in the North-East Region of India. The goal was to build sound structures in less vulnerable parts of the region or to assess the feasibility of building in certain areas.

The predominant frequency, is a soil characteristic that determines the weaker frequency range of the soil layer. This is important to know, as structures designed to withstand certain frequency ranges may not be able to withstand the frequencies present in a specific site.

The use of strong-motion data in the analysis helped to visualize how stronger and higher magnitude earthquakes would impact a specific site. This information is important for understanding the level of risk associated with building in a certain area, and can inform decisions about whether or not to build in a certain location, or what kind of building design is needed to make sure it can withstand earthquake shaking. Overall, this analysis was done to ensure that adequate measures are taken to minimize damage and ensure safety for the people living in the Assam and Meghalaya of India during earthquakes.
Horizontal to Vertical Spectral Ratio predominant frequency range of PESMOS stations of North-East India averaged between (0.40-1.70) Hz and peak Fourier Amplification Ratio of averaging 8.0 which comparable to the findings of Borah S., Goswami D, and Pathak J. (2016)'s work in the field of HVSR i.e., predominant frequency range of (0.50-2.00) Hz and peak Fourier Amplitude Ratio of 8.0.

6.2 Scope for further Study

With more seismic records across the region, we can estimate and identify the region or site which needs extra precaution while designing structures. Also, borehole data of specific sites can be used for evaluating the predominant frequency and site amplification.
With a sufficient amount of data, a contour map or heat map can be drawn out for a larger region.

And also liquefaction potential of a site using 1-Dimensional Equivalent Linear Site Response Analysis. This study can provide vital information about a site which is vulnerable to liquefaction and thus we can take necessary actions to avoid a catastrophe. Being in seismic zone area utmost care must be taken for construction, consultation and analysis before such super-structure or any structure must be done for the safety of everyone.

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Appendix I
Tables
Table I-1.1 Pesmos Stations

Sl. No.	Station Name	Station Code	Latitude (N°)	Longitude (E°)	Site Classification
1	Boko	BOK	25.976	91.230	C
2	Goalpara	GLP	26.152	90.627	C
3	Golaghat	GOL	26.516	93.972	B
4	Guwahati	GUW	26.190	91.746	C
5	Hailakandi	HKD	24.682	92.563	C
6	Kokrajhar	KOK	26.400	90.261	C
7	Lakhimpur	LKH	27.239	94.107	C
8	Tezpur	TZP	26.619	92.797	B
9	Tinsukia	TIN	27.503	95.332	C
10	Silchar	SIL	24.830	92.801	D
11	Darjeeling	DJL	27.050	88.262	C

Table I-1.2 Cosmos Stations

Sl. No.	Station Name	Station Code	Latitude (N°)	Longitude (E°)	Site Classification
1	Shillong	SHIL	25.57N	91.90E	ROCK
2	Nongstoin	NONS	25.51N	91.27E	ROCK
3	Nongpoh	NONG	25.91N	91.88E	ROCK
4	Dawki	DAUK	25.19N	92.03E	SOIL
5	Nongkhlaw	NONK	25.69N	91.640E	ROCK
6	Ummulong	UMMU	25.52N	92.16E	ROCK
7	Umsning	UMSN	25.74	91.89E	ROCK
8	Saitsama	SAIT	25.72	92.390E	SOIL
9	Mawphlang	MAWP	25.46	91.710E	ROCK
10	Haflong	HAFL	25.17N	93.020E	SOIL
11	Diphu	DIPU	25.92N	93.440E	SOIL
12	Bokajan	BOKA	26.02N	93.770E	SOIL
13	Barpeta	BAR	26.332 N	91.006 E	SOIL

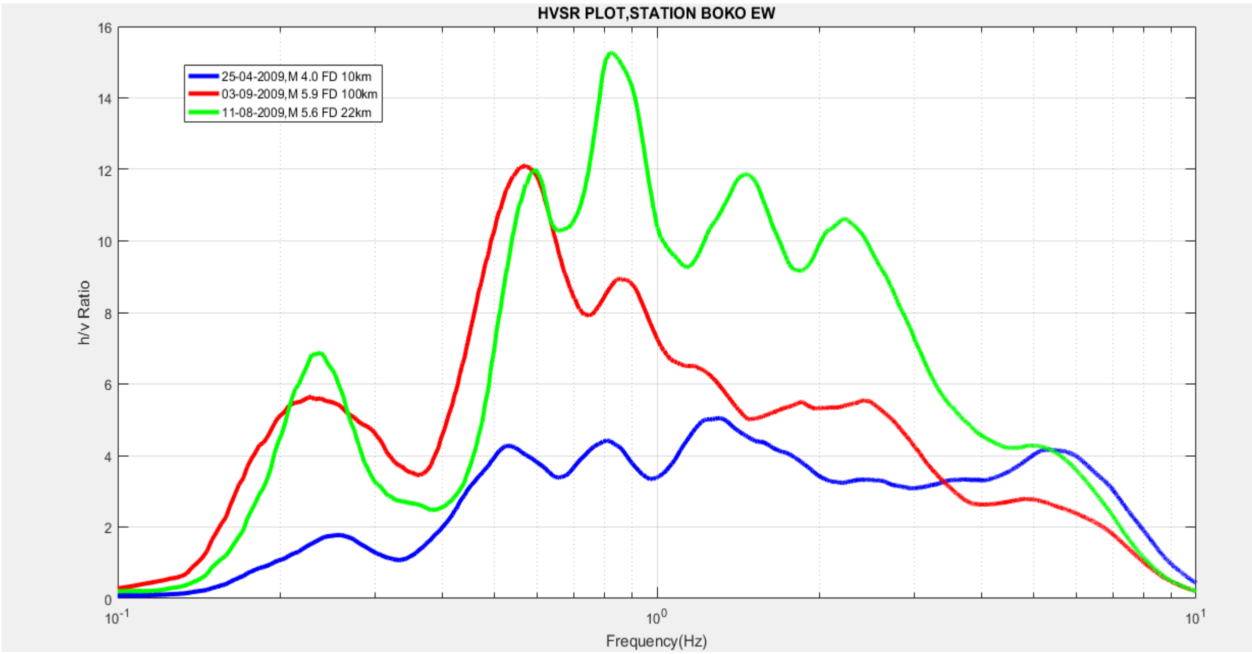
Table I-4.2.a PESMOS HVSR RANGE

STATIONS	FREQUENCY RANGE (Hz) EW
Boko	0.6-2.0
Goalpara	0.4-1.75
Golaghat	0.5-1.25
Guwahati	0.6-2.0
Hailakandi	0.2-0.8
Kokrajhar	0.4-0.9 & 1.75-2.9
Lakhimpur	0.4-0.9
Tezpur	0.6-1
Tinsukia	1.4-2.6
Silchar	0.3-1.25
Darjeeling	0.5-1

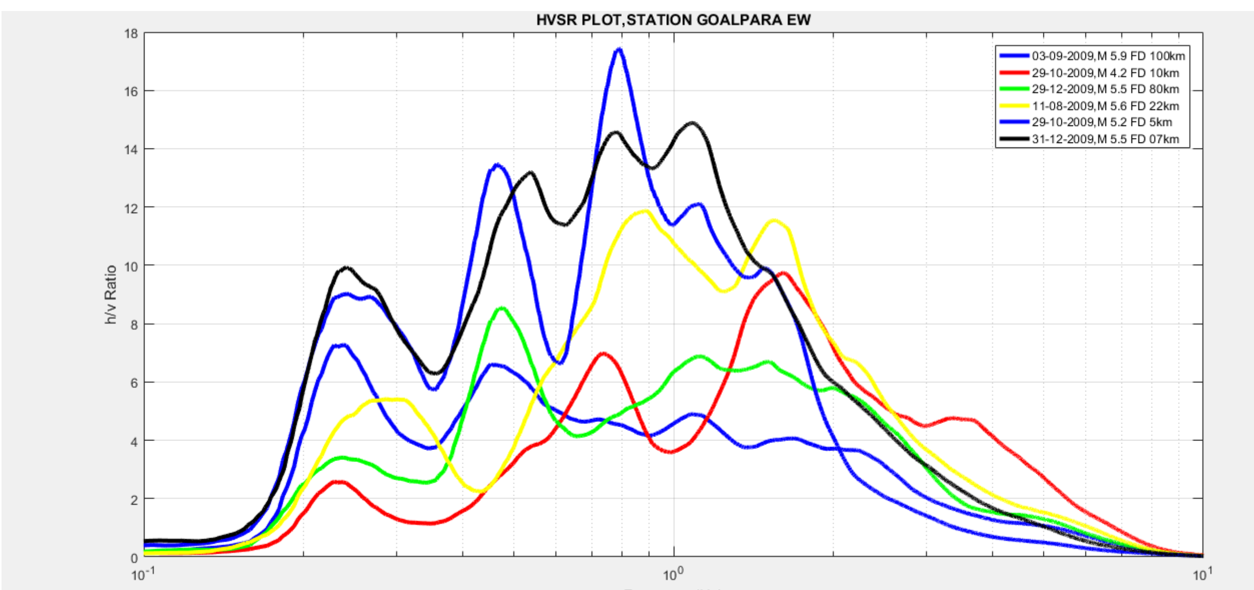
Table I-4.2.b COSMOS HVSR RANGE

STATIONS	FREQUENCY RANGE (Hz) EW
Shillong	3.72-4.66
Nongstoin	3.381-5.78
Nongpoh	4.83-5.92
Dawki	1.007-1.43
Nongkhlaw	2.41-3.515
Ummulong	6.39-7.50
Umsning	1.1-3.58
Saitsama	2.81-5.72
Mawphlang	4.28-6.16
Haflong	0.89-1.25
Diphu	2.14-5.16
Bokajan	1.062-2.72
Barpeta	0.81-1.41

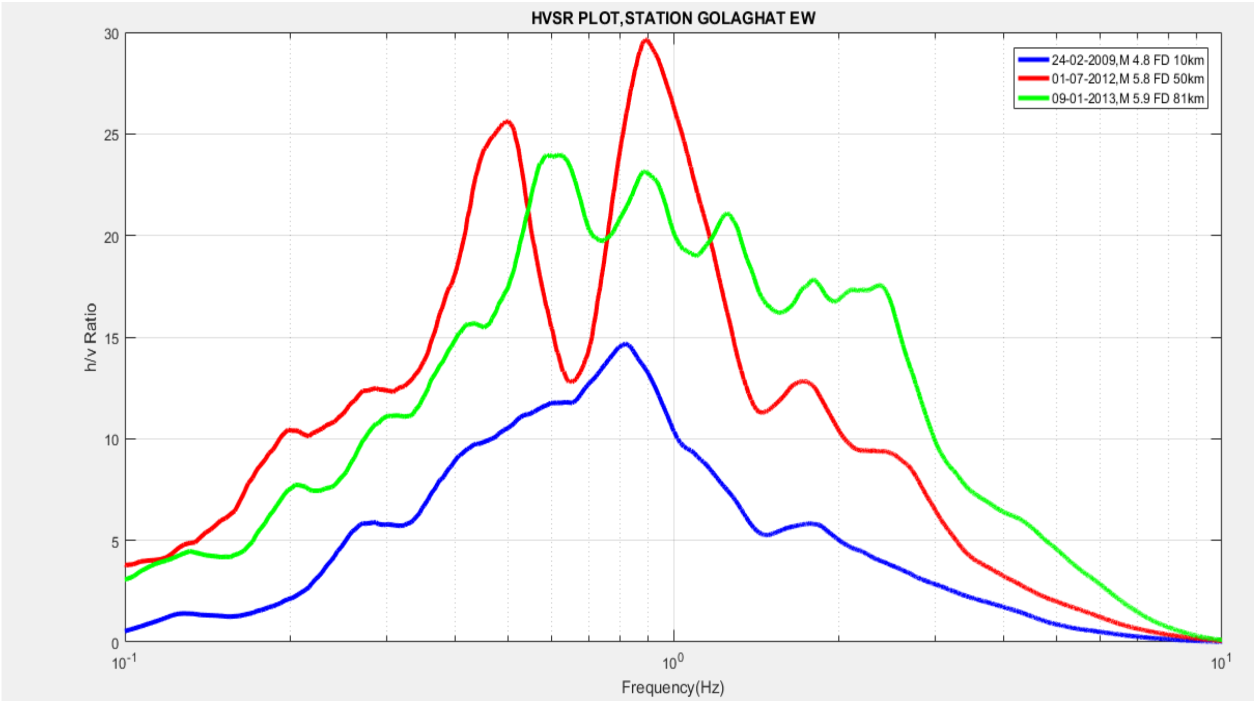
Appendix III
Pesmos Stations



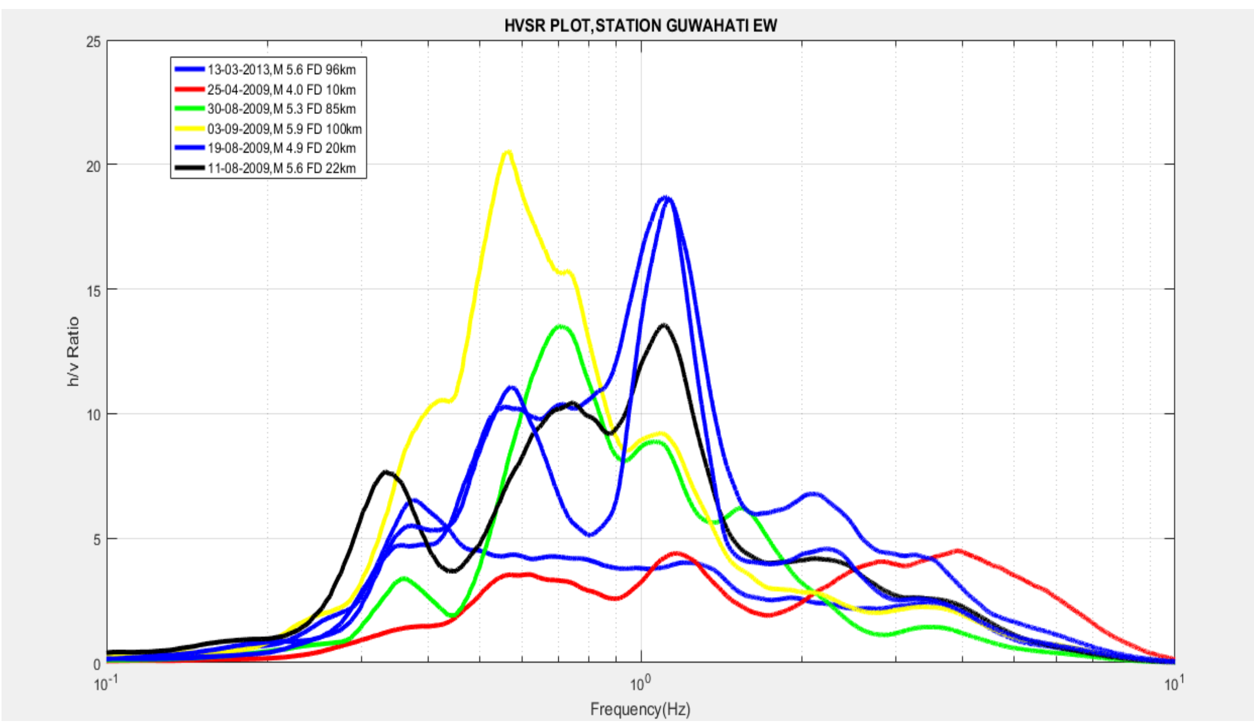
FigIII 4.1 HVSR Plot Boko EW



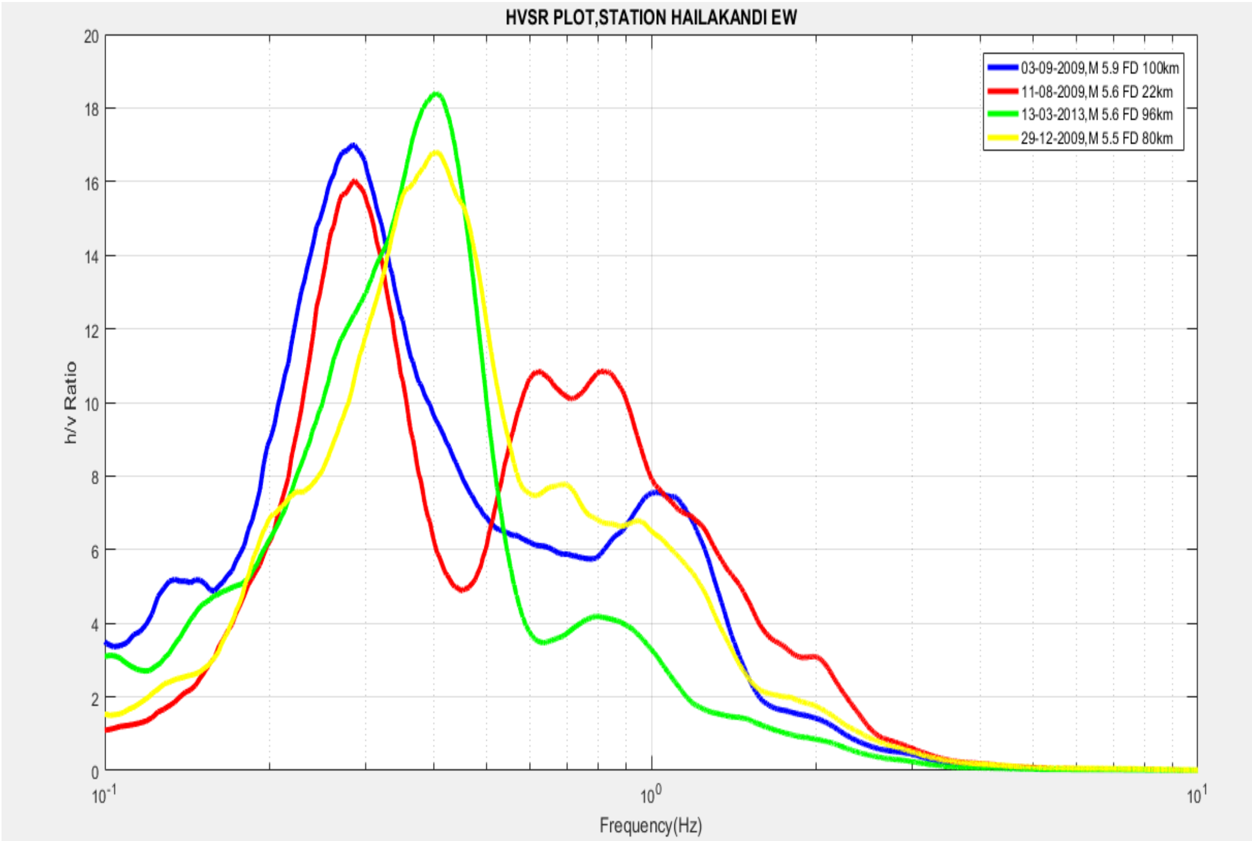
FigIII 4.2 HVSR Plot Goalpara EW



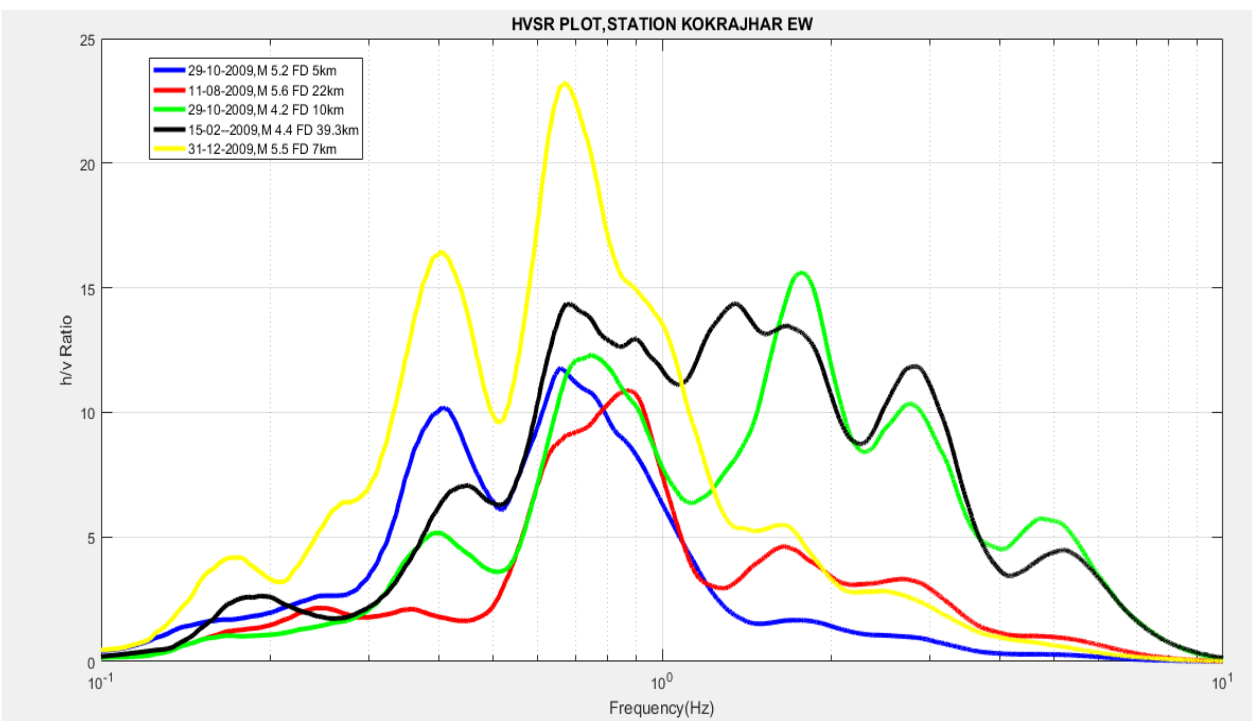
FigIII 4.3 HVSR Plot Golaghat EW



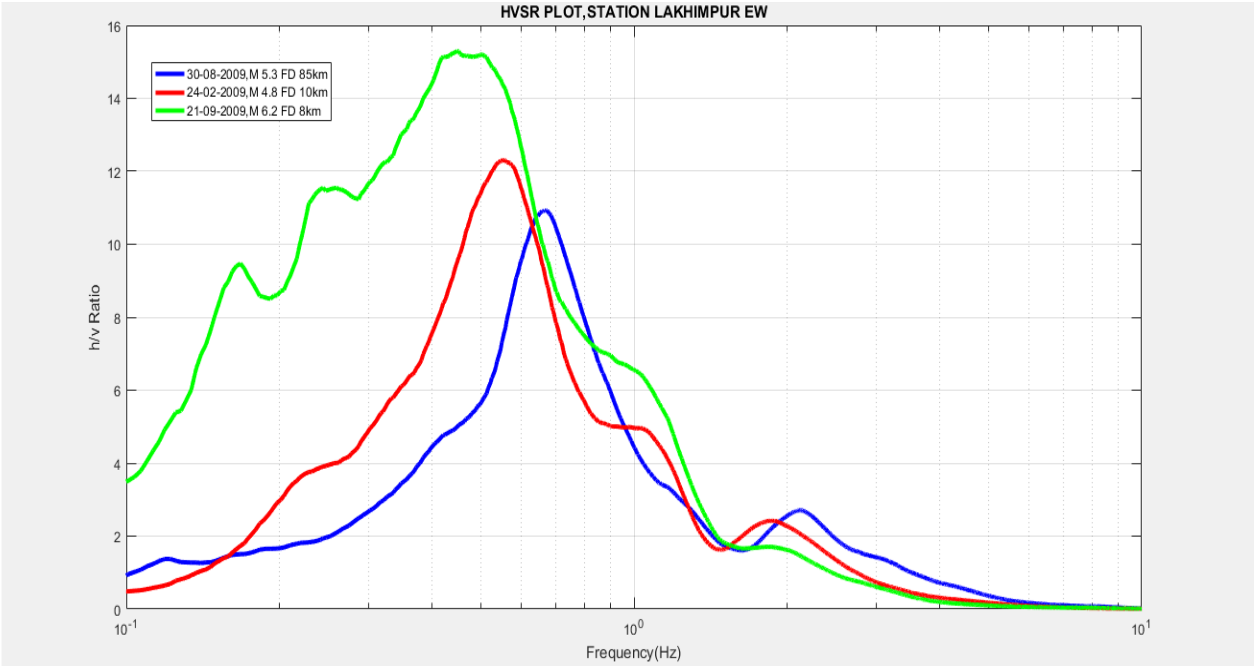
FigIII 4.4 HVSR Plot Guwahati EW



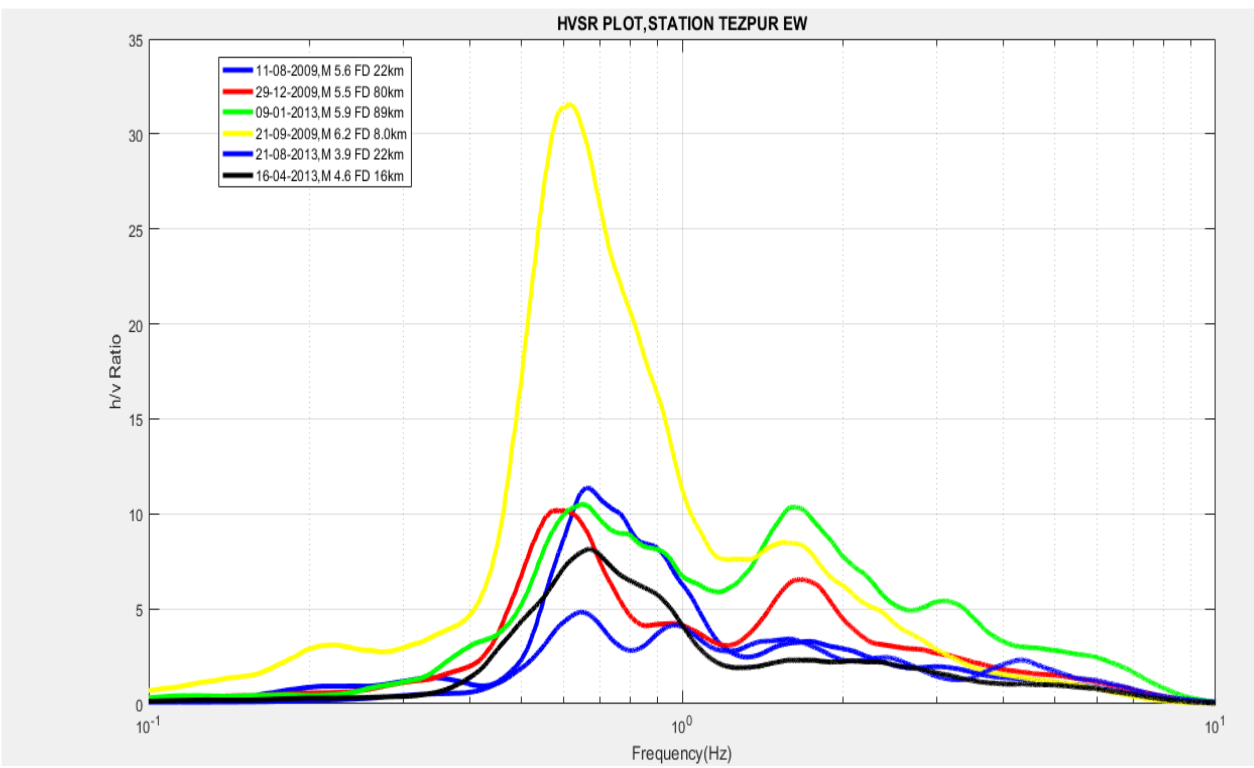
FigIII 4.5 HVSR Plot Hailakandi EW



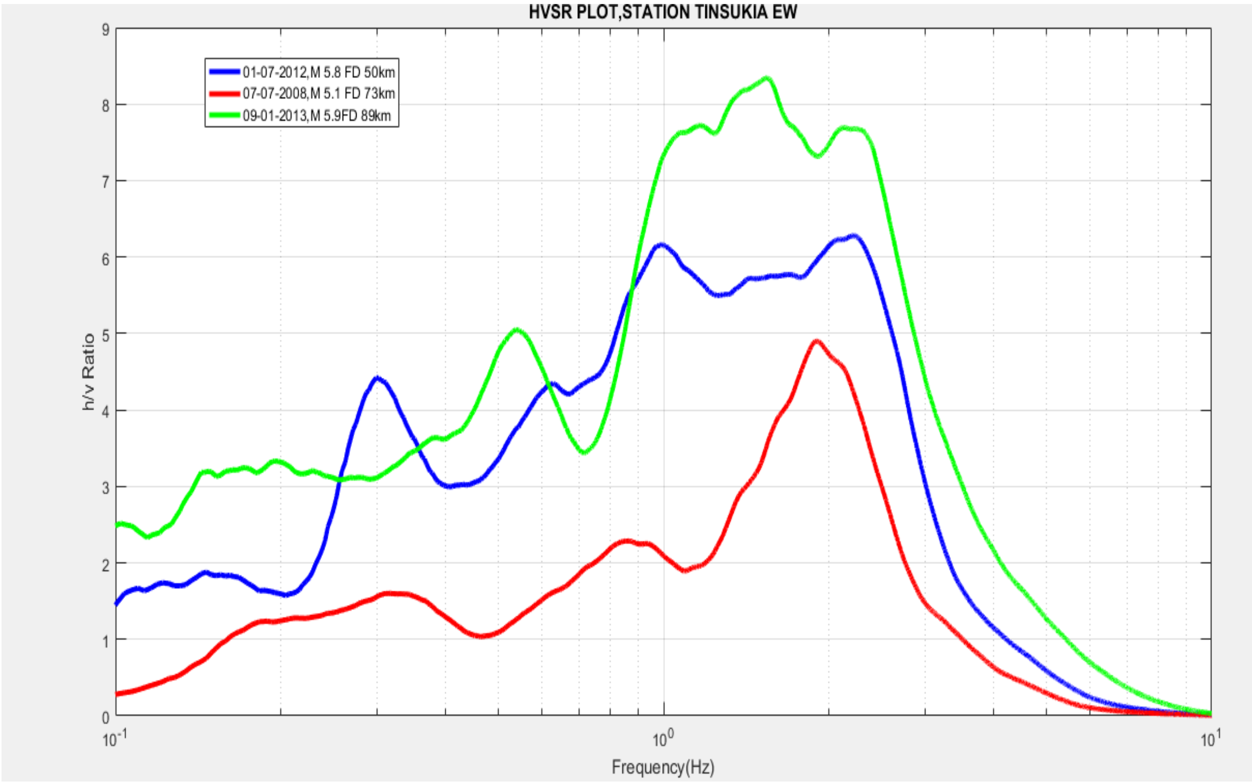
FigIII 4.6 HVSR Plot Kokrajhar EW



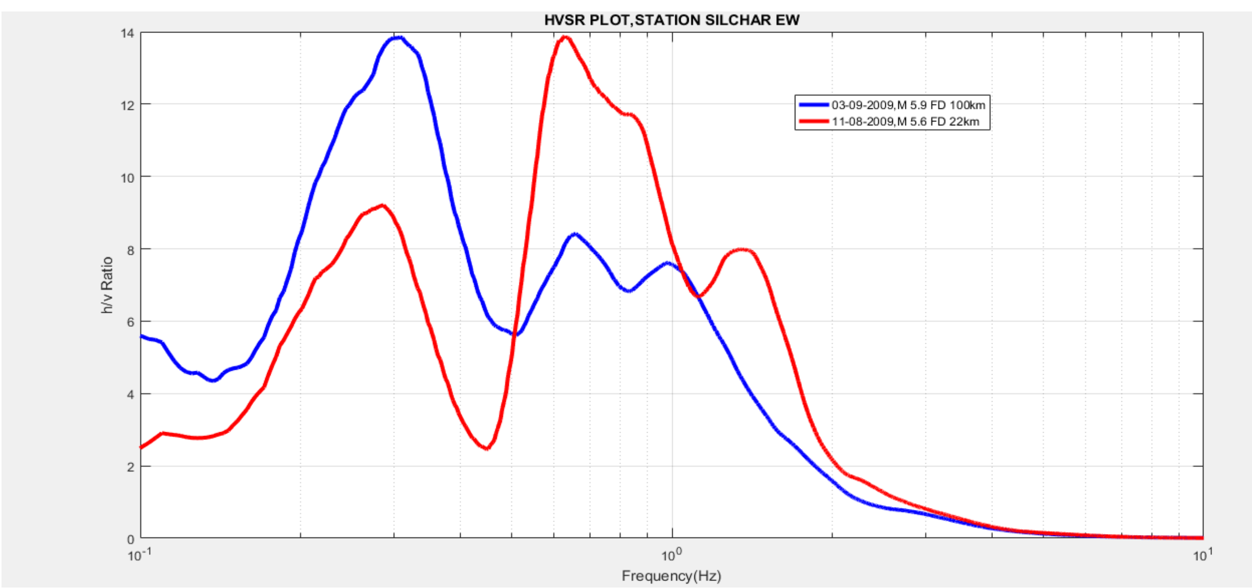
FigIII 4.7 HVSR Plot Lakhimpur EW



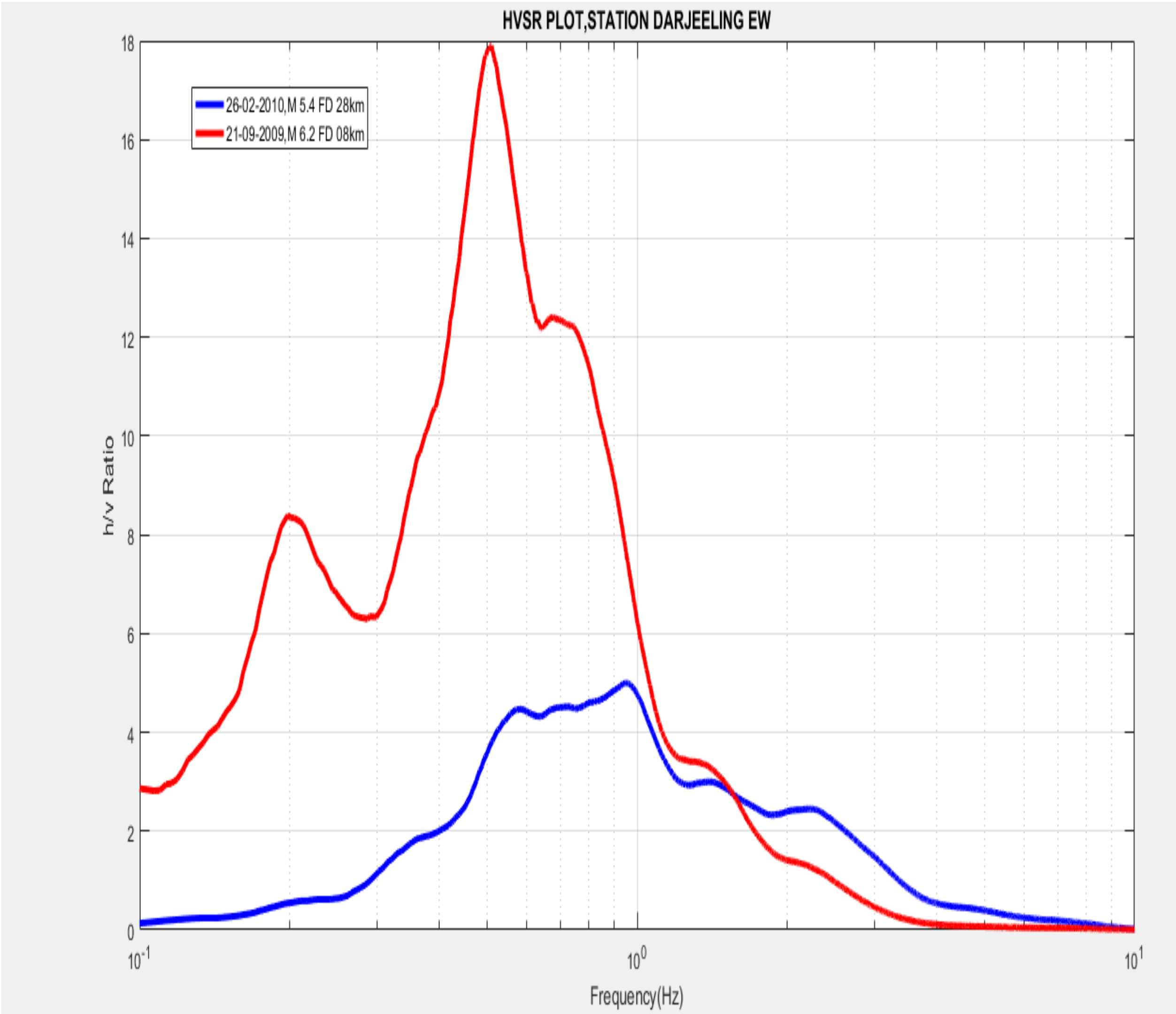
FigIII 4.8 HVSR Plot Tezpur EW



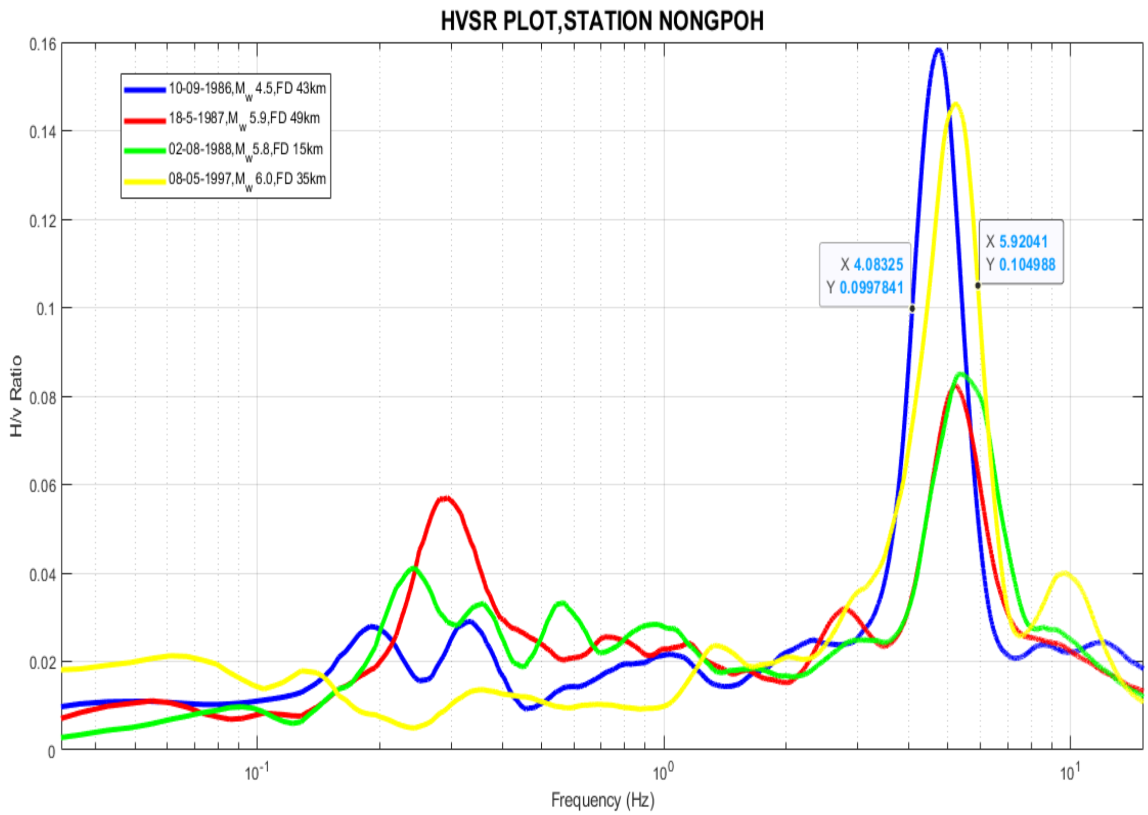
FigIII 4.9 HVSR Plot Tinsukia EW



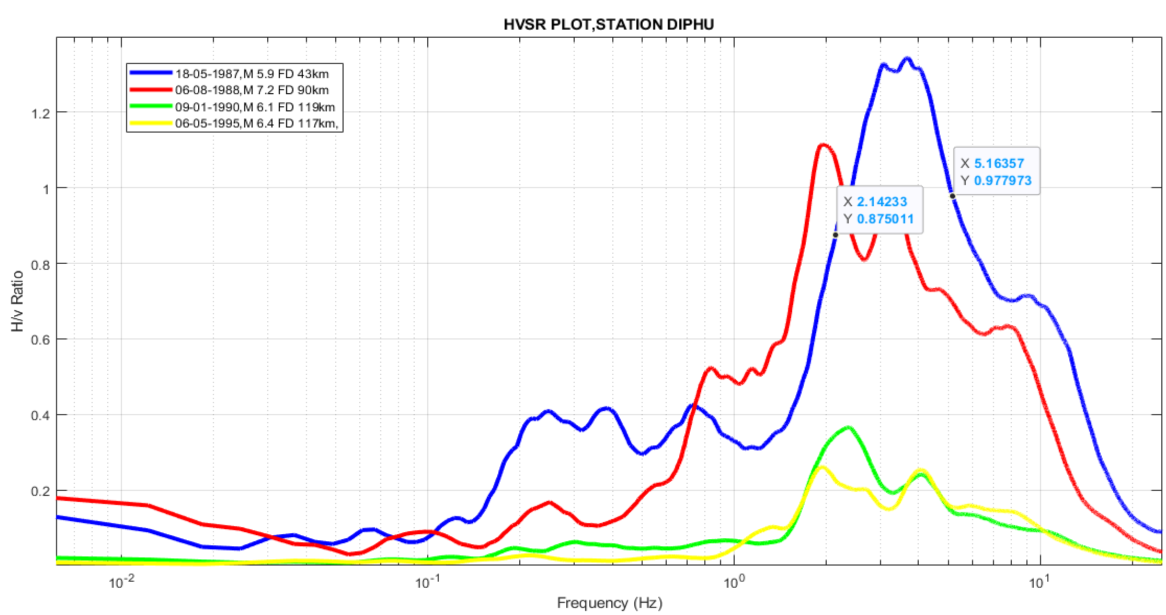
FigIII 4.10 HVSR Plot Silchar EW



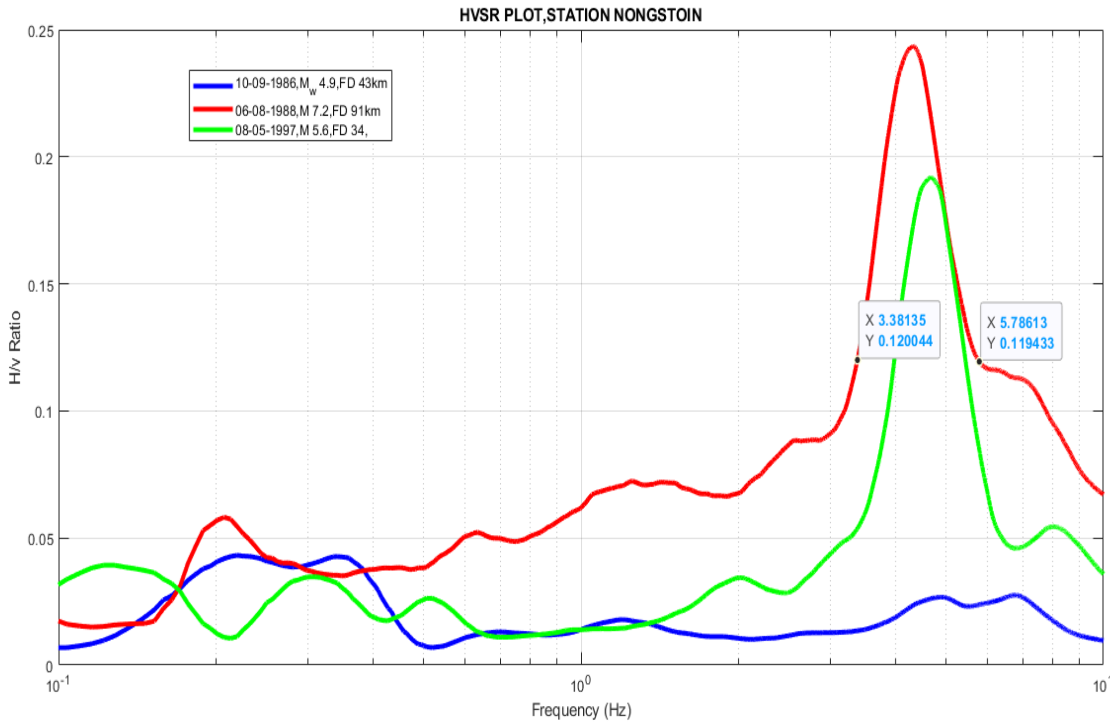
FigIII 4.11 HVSR Plot Darjeeling EW



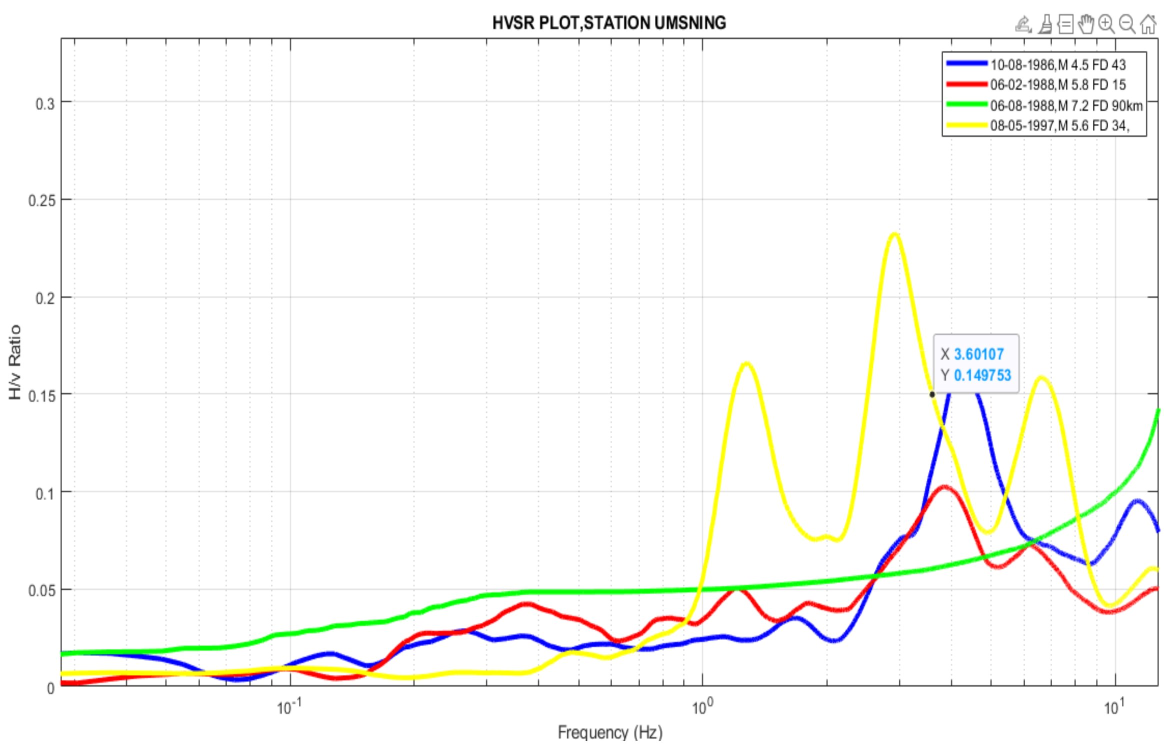
FigIII 4.12 HVSR Plot Nongpoh L



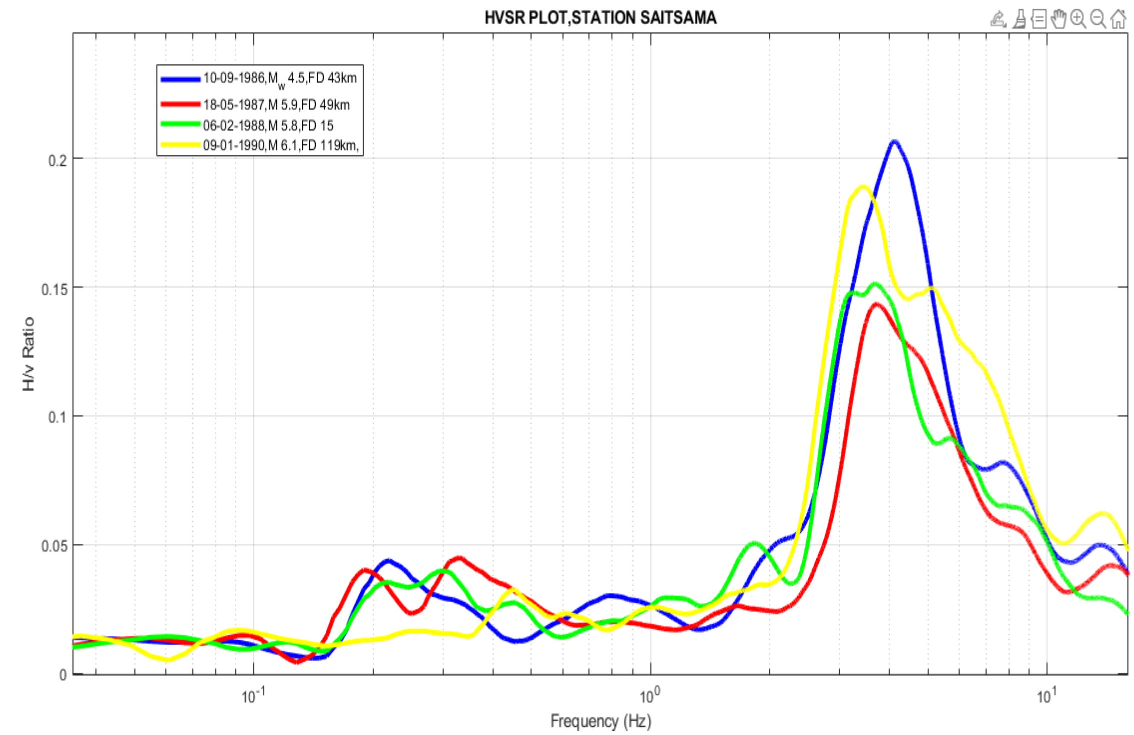
FigIII 4.13 HVSR Plot Diphu L



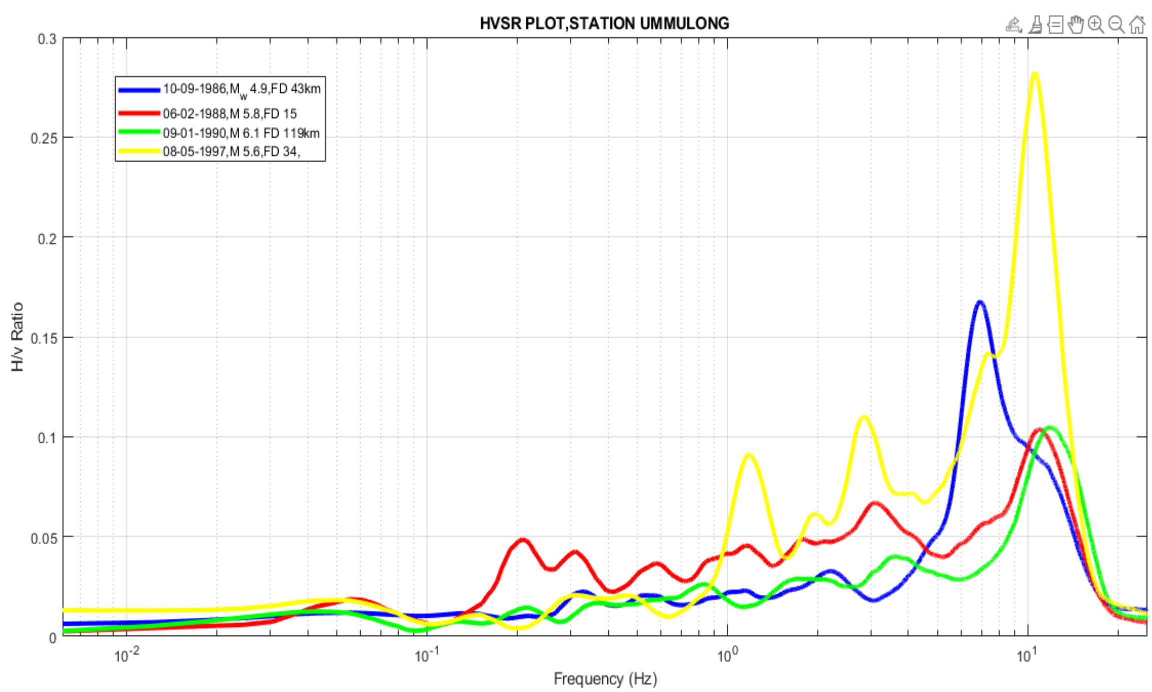
FigIII 4.14 HVSR Plot Nongstoin L



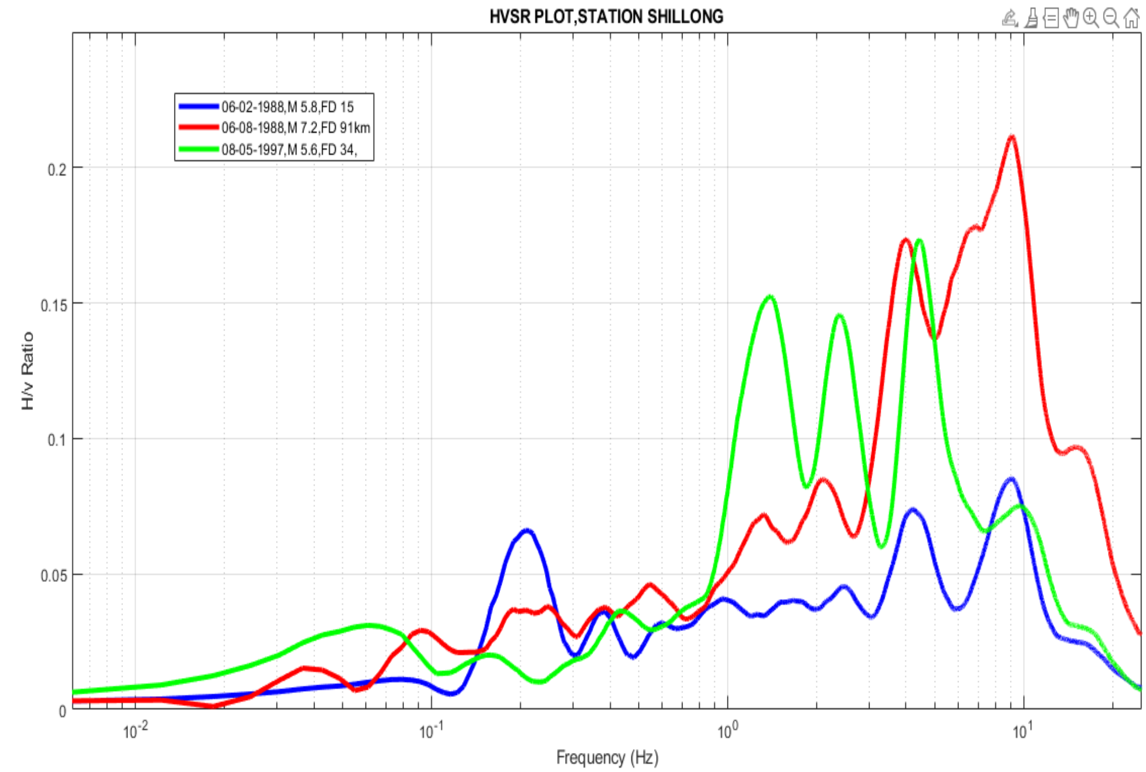
FigIII 4.15 HVSR Plot Umsning L



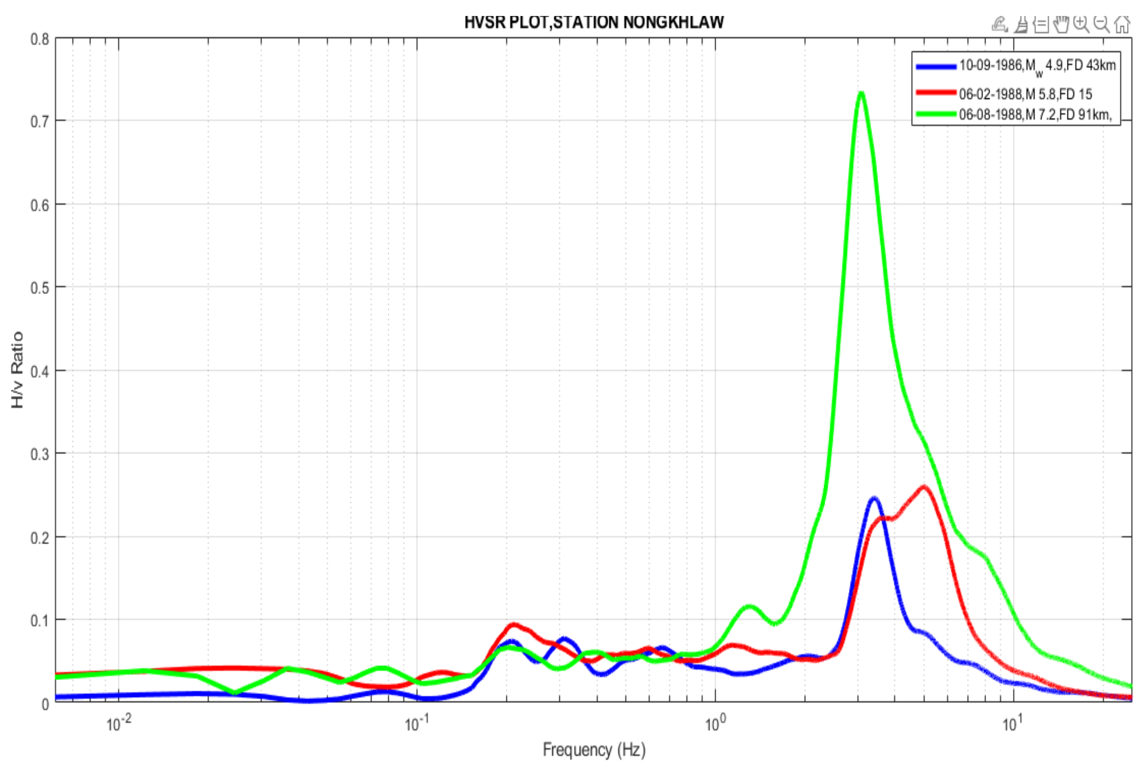
FigIII 4.16 HVSR Plot Saitsama L



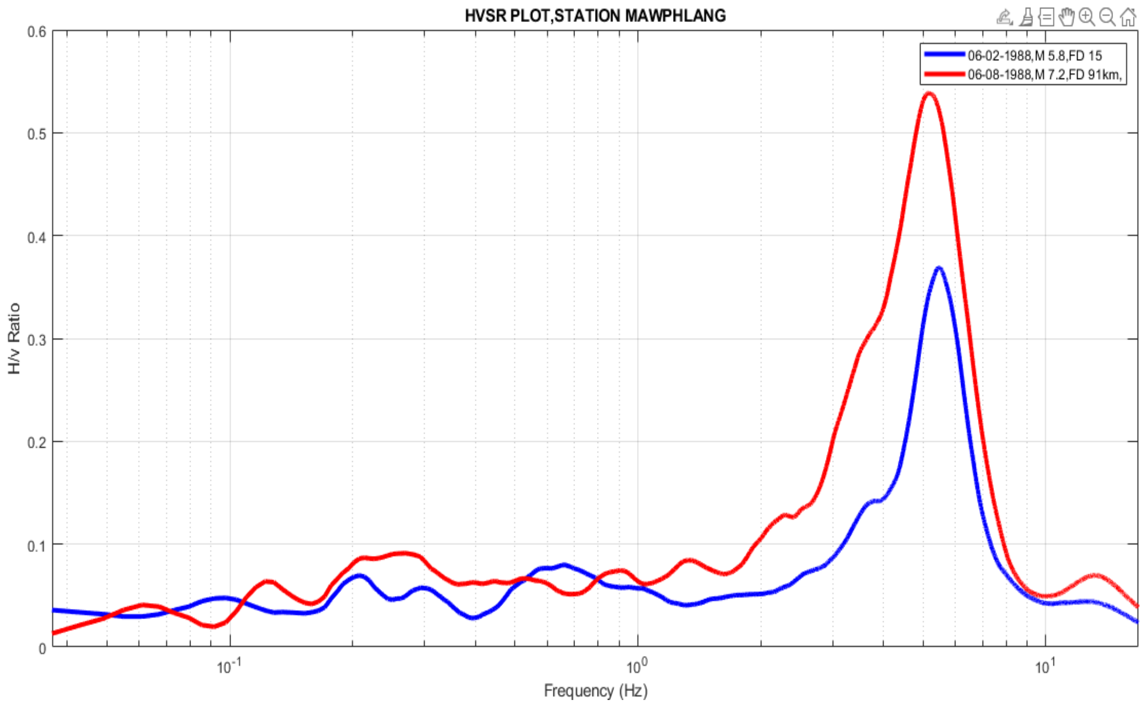
FigIII 4.17 HVSR Plot Ummulong L



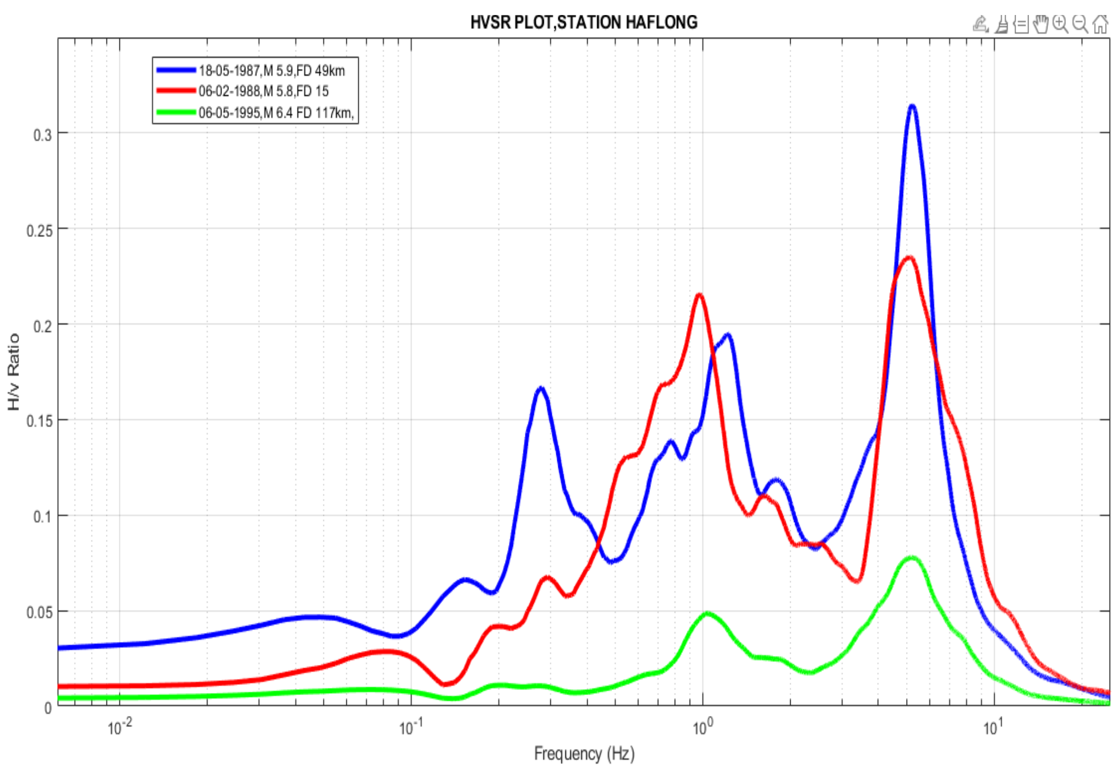
FigIII 4.18 HVSR Plot Shillong L



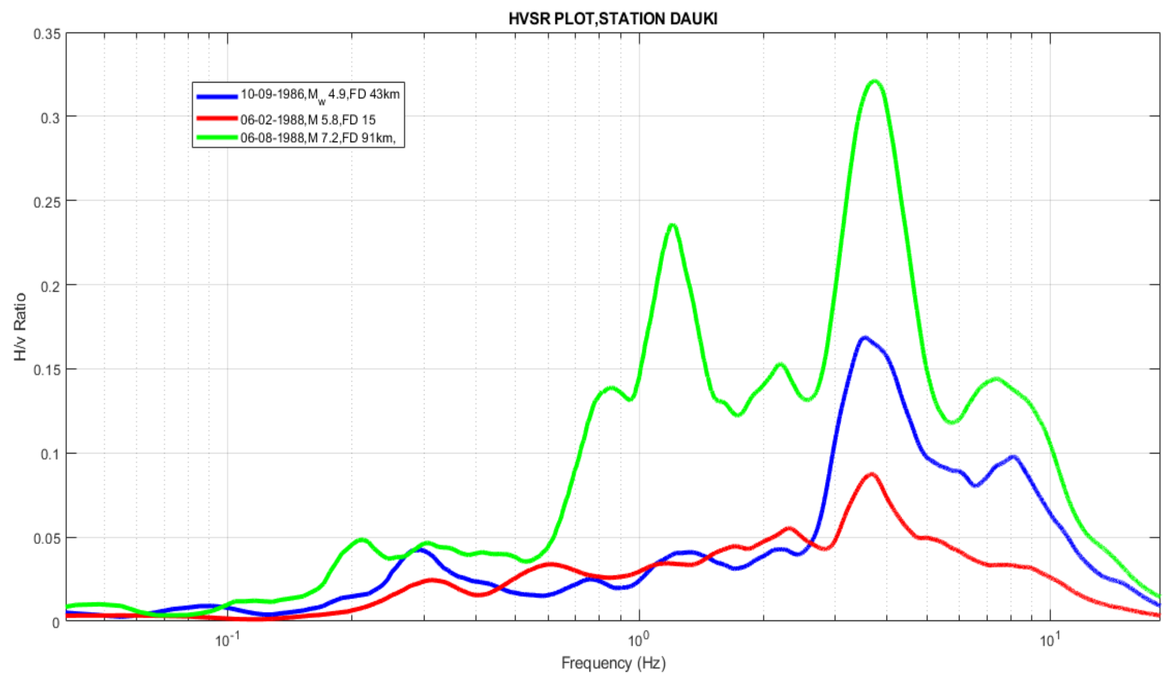
FigIII 4.19 HVSR Plot Nongkhlaw L



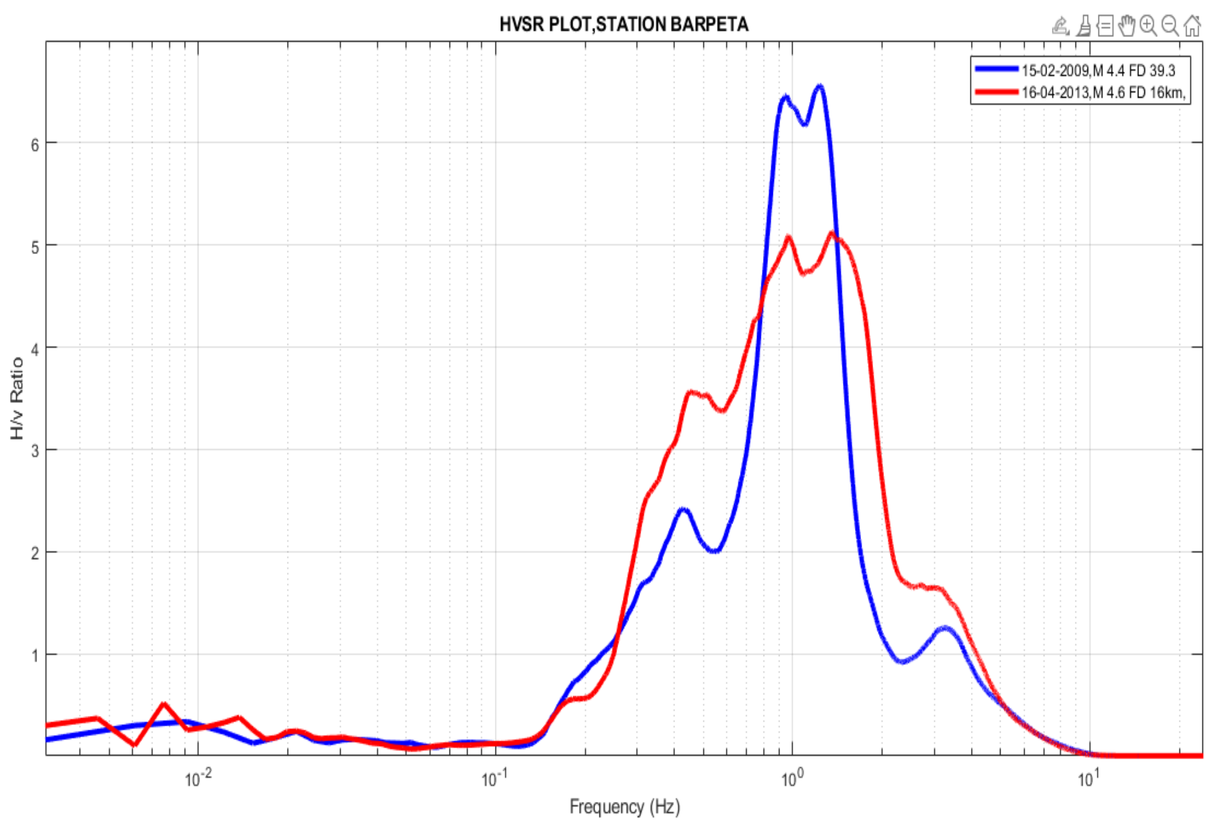
FigIII 4.20 HVSR Plot Mawphlang L



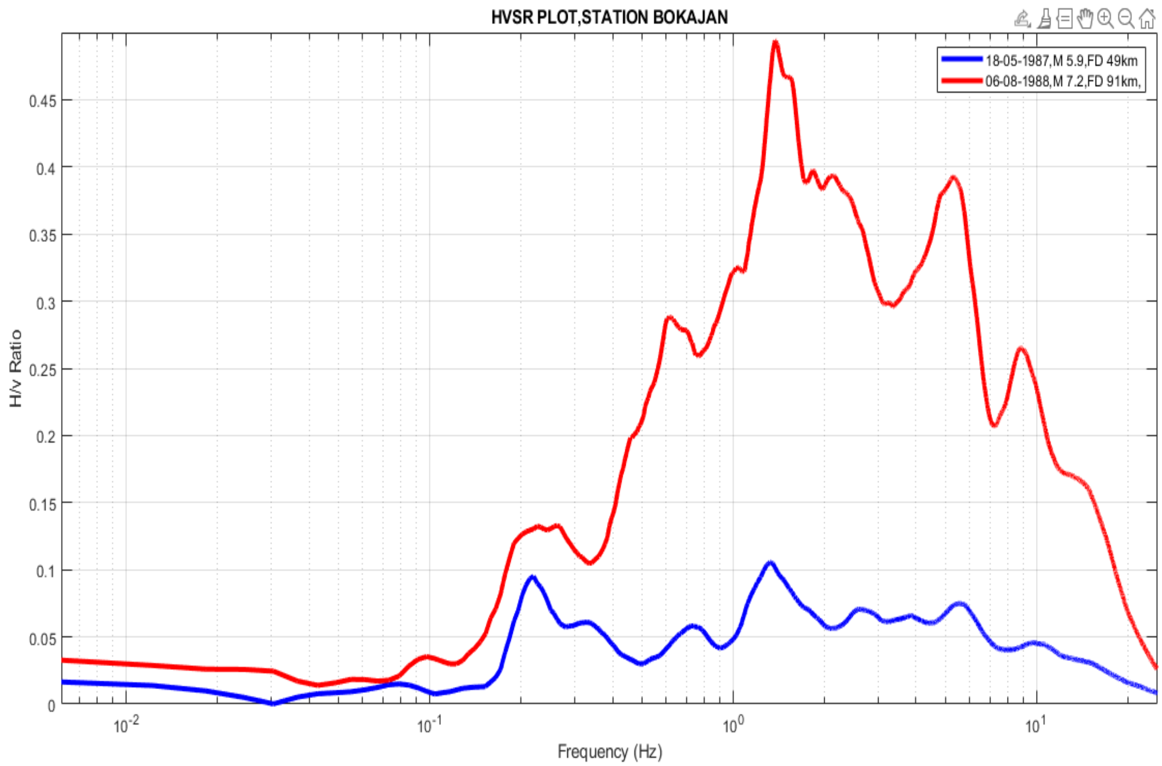
FigIII 4.21 HVSR Plot Haflong L



FigIII 4.22 HVSR Plot Dawki L



FigIII 4.23 HVSR Plot Barpeta L



FigIII 4.24 HVSR Plot Bokajan L