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Earthquake monitoring over Indian domain

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ABSTRACT

Seismic events are most disastrous and unpredictable natural hazard which occurs almost instantly. Recent advancement of sensor technologies, automatic processing, data acquisition, digital processing and smarter communication play an important role to provide adequate information almost instantly. National Centre for Seismology (NCM), Ministry of Earth Sciences (MoES) plays an important role in real time monitoring of seismic activities in Indian region and neighboured. Precise and timely information reception and dissemination of seismic tremors is the key of success and mainly depends on the selection and robustness of the seismic stations. Therefore, it is essential to minimize the influence of undesirable or unrealistic vibrations and disturbances around the selected seismic stations. In this paper authors utilized a statistical method called Probabilistic Power Spectral Density (PPSD) based on the standard spectral density plots generated through SEISAN software program running at National Seismic Centre (NSC), New Delhi. The strength of robustness of any station depend on the increase in ambient vibration levels which can be reflected in lower and upper tolerance limits of plots generated. This analysis is very useful in diagnosing the seismic noise in digital seismic telemetric monitoring network and in determining the noise conditions in selected sites before establishing a countrywide seismic network of Indian domain. PPSD analysis is useful for long-term vibration behaviour of the selected stations or observed area. For brevity, authors have presented the analysis of six stations only and it has been found that the noise levels were confined within new LNM and HNM and can said have good performance. However, the cultural effects cannot be ignored completely.

Keywords: *National seismic centre, power spectral density, national seismic network & systematic background noise (SBN).*

1. Introduction

National Centre for Seismology (NCM) under Ministry of Earth Sciences (MoES) has 152 stations of National Seismological Network spread all over the country with latest state of art instruments (Figure 1). Total number of earthquakes recorded for the month of July was 71 out of which 34 earthquakes occurred in Andaman Sea and 5 earthquakes occurred in Manipur and Mizoram (NCS technical report, July-2022). Figure 1 (a) represents the graphical waveform generated after operationally processed at NCS Delhi. This centre is operated 24x7 for monitoring the earthquakes, India and neighboured. The red colour represents the most affected area having strong magnitude of earthquake and needs attention to the public. The advanced prediction is still a challenging task and efforts are continuing world over to find out the suitable tracers based on that a forecast can be given to the public. However, micro zonation and other precursor based studies characterized the Indian domain in different zones based on the severity. This information was found very useful in making the seismic resilient buildings and other infrastructures.

Technologically the monitoring network is gradually advancing starting from old seismic activity monitoring network which were equipped with weak motion monitoring sensors having issues in differentiating other ground wave vibrations to advanced automatic sensors. More precisely, seismic monitoring requires (i) a sensor (seismometer) that converts vibratory ground motion into an electric signal, (ii) a local recorder or a communication network that transmits this signal to a data center, and (iii) analysis at this center that combines the signals from many seismometers to determine a location, magnitude

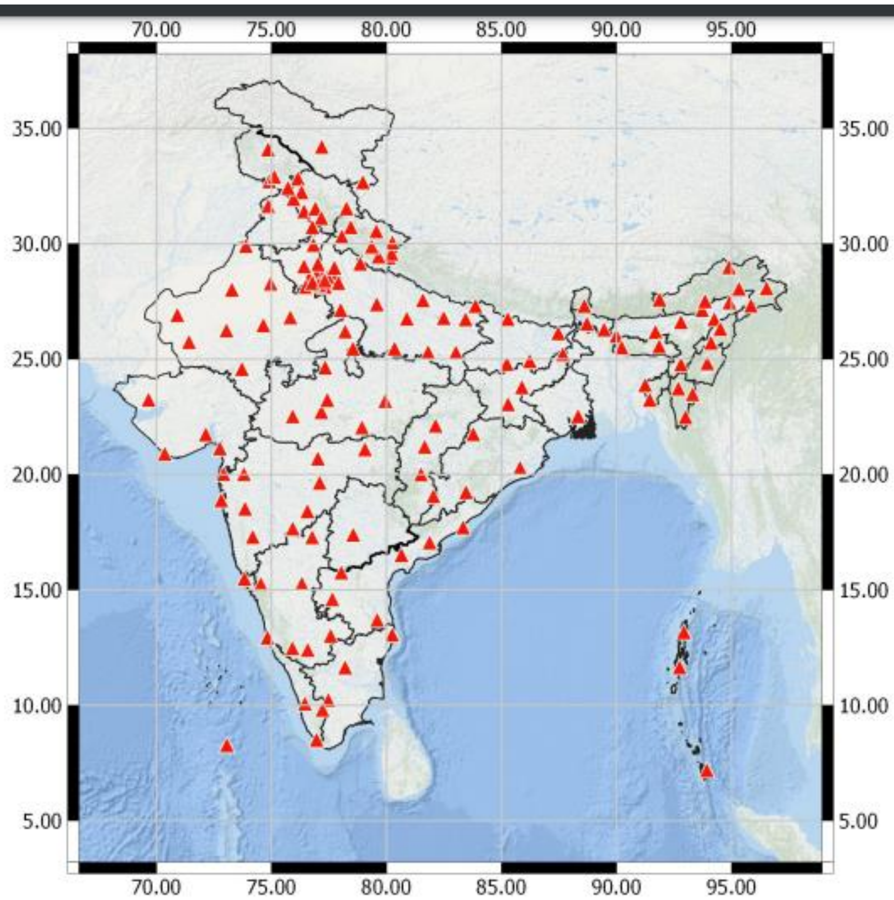

Figure 1: National Seismological Network (152 stations)-Ministry of Earth Sciences (MoES).

peak acceleration, and other parameters that characterize the source and nature of the event. These sensitive monitoring systems are essential for continuous surveillance and for characterizing many important details of earthquake occurrence throughout India and global. Normally, the ideal seismograph has high dynamic range and resolution and broad-band recording capability and modern instruments have digital recording with better background Earth noise data.

The National Seismological Network (NSN) of India has a history of more than 120 yr. During the last two decades, the NSN has gone through a significant modernization process, involving installation of seismic stations equipped with a broadband seismograph (BBS) and a strong-motion accelerograph (SMA), Bansal et al., 2021.

The capabilities of the national seismological network of India has been strengthened over the years and is now capable of estimating the main earthquake source parameters within ~ 5–10 min with an average of about 8.0 min (Bansal et al., 2021).

Earthquakes events worldwide is of great concern and automatic seismic analyses are becoming an increasingly urgent demand, because of the huge amount of data to be processed and the growth of more and more specific applications (Vigano et al., 2021). Real-time earthquake information is shared in many ways to meet the needs of different end users (citizens, technicians, civil protection, politicians, and decision makers) (National Research Council 2006). World-wide timely alerts for earthquake occurrence need to be appropriately prepared, in terms of logical sense, completeness, and clarity (Lamontagne et al. 2016). Automatic processing through Seisan software (Havskov and Ottemoller, 1999) have many advanced processing features like, epicentre/hposenter location determination, trace plotting, phase picking and spectral analysis, plotting epicentres, searching and extracting events from database, inserting, updating the events, making bulletins, reports and statistics, waveform file management, file conversion and modifications, signal processing, fault plane solution, merge events in real time, making and

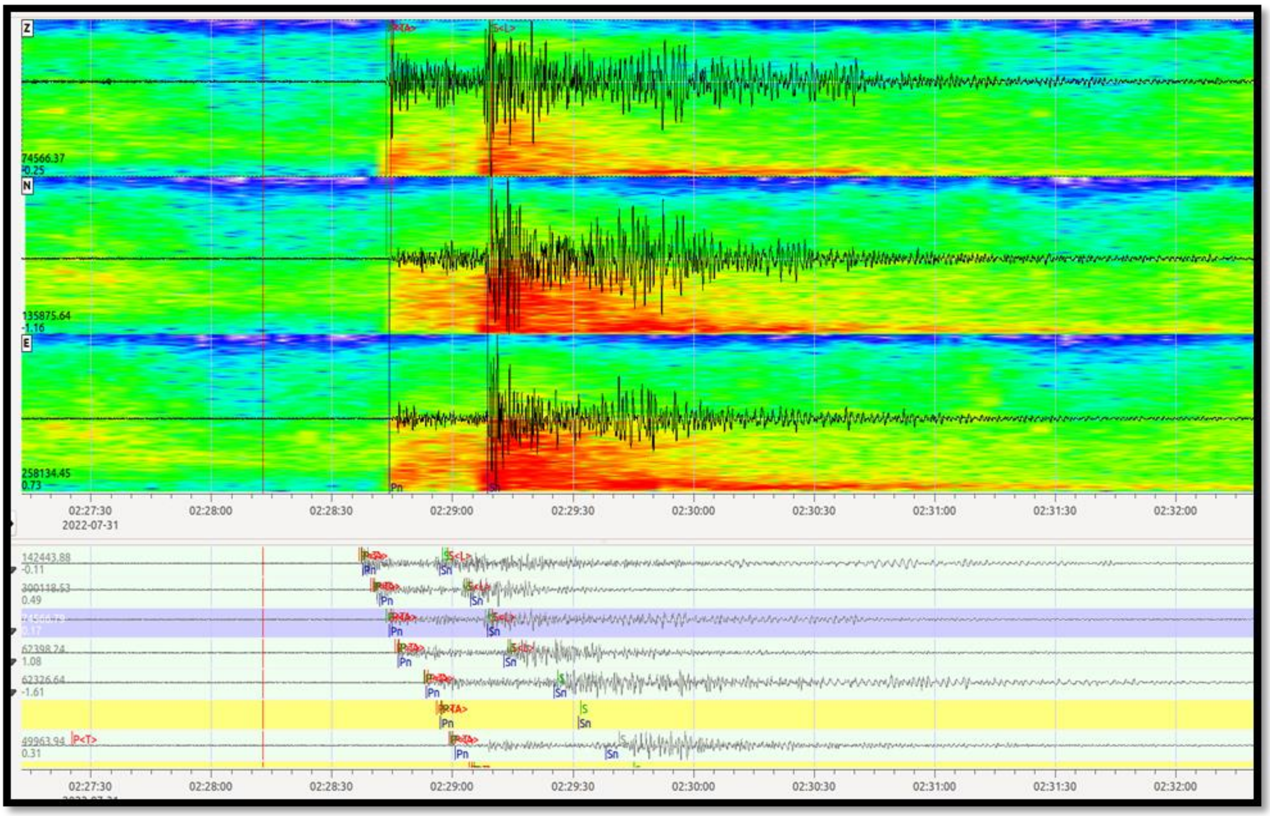

Figure 1 (a): Nepal Earthquake 31st August-2022 of Intensity (4.9) operational generated waveforms at stations STMR= Sitamarhi, GTK =Gangtok JPG= Jalpaiguri SHBG= Sahibganj COBR=Coochbehar DHUB: Dhubri (Meghalaya).

plotting synthetic seismograms, calculation and plotting of travel times, topographic inversion, seismic risk calculations, magnitude calculation, local magnitude inversion, explosion filtering, inversion of travel time data, joint hypocentre determination, slowness analysis, surface wave analysis, instrument response, macroseismic database, correlation of waveform signals, detection of event clusters etc. Worldwide automatic seismic processing software have very effective in the identification of not only P-picks but also S-picks, which are essential to achieve high quality locations (Scafidi et al. 2016, 2018, 2019).

In recent past PPSD analysis has successfully attempted by many parts of India and elsewhere by various researchers. N. Jana et al, 2017 performed seismic background analysis to assess the ambient seismic noise levels presents in the sensor data at Eastern Ghat Mobile Belts (EGMB), Orissa, India. Similar type of data analysis has been done in Bulgaria (L. Dimitrova., 2009), High Agri Valley (T. A. Stabile et al., 2019) & in Austria (F. Fuchs et al.,2015) to study the seismic noise in broadband NationalOperative Telemetric System and noise conditions before establishing network.

2. Data and Methodology

The events and station data utilized in this study has been taken from National Seismic Data Centre, Ministry of Earth Sciences (MoES), Lodi Road, New Delhi. Operationally, SEISNET and SEISAN analysis software (Havskov and Ottemoller, 2000) is used for real time monitoring of the seismic events at NCS. The new sites tested thoroughly before finalizing for operational purposes. The methodology of suitability of a site depends on the spectral density variation with time each segments around the station. Each segment has separate Power Spectral Density function which is calculated using a Fast Fourier Transform spectra and spectral components and its own power or contribution depending on the site location and surrounding environment. If the conditions are uniform or homogeneous then the distribution of the power in each spectral components differ much and noise spectrum also behave in the same manner. The standard approach is that the values of full-octave averages in 1/8 octave intervals are calculated for each of the acquired PSD functions. The power values is then converted into m2 /s4 /Hz (acceleration derived from measured velocity) to dB range (to represents in maps appropriately), under the assumption that the reference acceleration a0 = 1 m/s2. The we generate the Probabilistic Power Spectral Density graph by discretizing the amplitude graphs by value (usually with discretization step of 1 dB) and counting the number of times the value of amplitude falls within a specified range bin (e.g., between -99 and -100 dB). This procedure is repeated for every amplitude of every frequency octave range of every PSD graph. When finished, the percentages are calculated based on the tallied data vs the total amount, and these percentages are plotted to form the actual PPSD graph (Lancy et al., 2020).

3. Results and discussions

Current operational seismic monitoring system should capture both weak and strong motion to provide the full range and spectrum of seismic information available and, through combined analysis, provide practical results that greatly exceed those previously realized in independent operations. The monitoring and magnitude wise reporting procedure of the seismic events adopted nationally are as follows: (a) M:2.5& above in and around NCR Delhi. (b) M:3.0& above for NE region (c) M:3.5 & above in Peninsular, extra-Peninsular, A&N and Lakshadweep Islands region of the country. For events in this region, if autolocation software auto-locate the event and estimated magnitude is below 3.5 after review by Duty Officer, then Level-2 message needs to be disseminated (d) M:4.0& above in the border region (6 to 38deg N and 68 to 98 deg E) (e) M:5.0 & above in the regions (0 to 40 deg N and 60 to 100 deg E) f) M:6.0 & above in any part of the world.

Regional centres also provide local expertise on earthquake hazards information for the local engineering and emergency management communities and for the general public, and they provide training for undergraduates and graduate students pursuing careers in seismology and related fields.

The upgradation is done by replacing old seismographs to modern seismographs, communication networks connectivity, data processing centers capabilities, and well trained personnel availability to work efficiently at 24 x7 basis. This integrated system would constantly record and analyze seismic data and provide timely and reliable information on earthquakes and other seismic disturbances. Micro zonation studies have been carried out for Delhi and neighboring area to designate vulnerable sites in urban areas and near major active fault zones to gather greatly needed data and information for reducing earthquake impacts on buildings and structures.

4. Power Spectral Density Probability Density Function (PPSD) function analysis

To check new site is suitable for seismic purpose of rot we perform PPSD analysis (Peterson. 1993). The noise present at a location based on the calculation of the distribution of power spectral density using a probability density function. To compute the PSD values we have to select a time series segment (like an hour or 24 hour) and then the instrument transfer function is removed from each segment, yielding ground acceleration and then it averaged to provide a PSD for each 1-hour time series segment. Then, for each channel or station we have raw frequency distributions by gathering individual PSDs in the following manner: binning periods in 1/8 octave intervals and binning power in 1 dB intervals. Each raw frequency distribution bin is normalized by the total number of PSDs to construct a PDF. Then probability of occurrence of a given power at a particular period is plotted for direct comparison to the Peterson high and low noise models (HNM, LNM). Each segment bin have maximum limit on both sides high and low noise levels and seismic noise information can be obtained from this f broadband seismic noise patterns of PPSD. The characteristics of ground motion near the location of the station can deduced based on the PPSD graph plotted from the data collected over one day. The vibrations caused by human activity generated from operating machines, manufactures, public transport etc. representing in the upper side and it will be at peak-level when human activity during the day maximum and the lower one to the nightly hours.

Variation of noise is clearly visible in both the high frequency and in the low-frequency bands for a period of larger than 10s. It has been generally observed that during winter time noise exceeds the limit of 10 dB below the normal high noise models (NHNM) for periods larger than 10s. Figures 2 (a) represents PPSD graphs obtained from ground motion data (vertical direction) of the seismic stations Agra. We know that PPSD analysis corresponds to the vibrational behaviour of the stations and high and low values indicates the highest and lowest measured levels of ambient noise around the station. Ajeet et al., 2020 done similar type of analysis for seismic background noise at national seismic network in India using PSD, Fourier spectra, Spectrogram, and HVSR approach, before and during the nationwide lockdown declared due to COVID-19 pandemic. In figure 2 (a) the value of the systematic background noise (SBN) varies and not consistent as it slightly exceed the HNM range. However in shorter domain period (< 1 s) the variation in SBN performance was found significant. For the stations Aizawal and Akola the noise level was within the HNM and LNM limit, figure 2 (b,c). Similar situation has been seen for Bhavnagar, Joshimath & Gangtok stations represented in figures 2 (d to f). In this analysis we have taken vertical component in consideration due to the fact that the horizontal components are noisier than the vertical components as its sensitivity depends to the tilts of the seismometers and the gravity effect is coupled to the horizontal components only (De Angelis, 2008). It has been observed from the study that noise levels go down about 8 -10 dB for the six stations presented in this work at period < 1.0 s during August, 2019. All the six stations presented in the figures 2 (a-f) have the noise levels were confined within new LNM and HNM and can said have good performance. However, the cultural effects cannot be ignored completely.

5. Concluding Remarks

The upgradation of the existing seismic monitoring network has improved the anlaysis and skills of the operational staffs in dragonizing the seismic activities. Latest state of art instruments and processing softwares have the capability to separate of functions between strong- and weak-motion monitoring systems. Risk analysis of different geographical areas has improved with timely dissemination of digital data.

The data quality and operational standards has improved and it helps to bring synchronization with global community. Real time digital transmission and dissemination of information improves further emergency management and seismic monitoring. Advanced systems have capability to generate automatically broadcast information when a significant earthquake occurs, for immediate assessment of its impact. Where feasible, for sites at distance from the epicenter, broadcast an early warning, seconds before strong shaking arrives. Current systems have an effective data management scheme for the integration, archiving, and distribution of seismic data collected by all monitoring elements of the advanced system. Traditional and new upgraded system bridges the gap between observation and implementation of hazard reduction strategies, through better probabilistic hazard assessment from better definition of seismically active faults and volcanoes, and through compilation of a complete catalog of earthquakes for the country. Acquisition of new data enhanced the basic research activities on earthquake process, propagation and site effects due to Earth structure, and prediction of ground motions for future, large damaging earthquakes in urban areas. It helps to provide better evaluation of the damage experienced by structures in strong ground shaking through new observations of strong shaking in urban areas exposed to high earthquake hazard. It also support for government for making national strategies for mitigation its impacts. To save life and properties and better infrastructure based on latest norms of architectural design, public-private partnerships can be an alternative. It will further an additional support for urban areas at risk where instruments are needed to measure strong ground motion in structures or in sparsely populated areas where denser instrumental coverage may be needed to enhance the safety of commercial facilities and infrastructure. The Probabilistic Power Spectral Density method presented in this

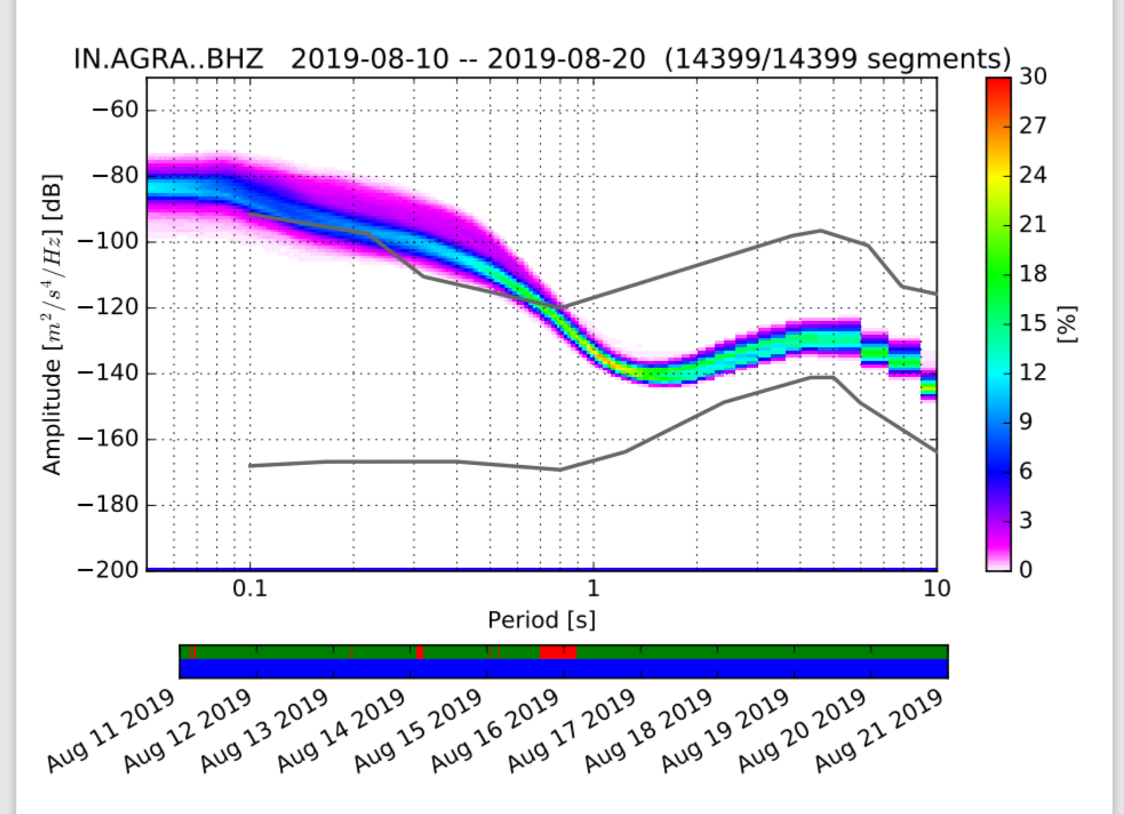

Figure 2 (a): PPSD analysis for Seismic Station at Agra (11-21 August-2019).

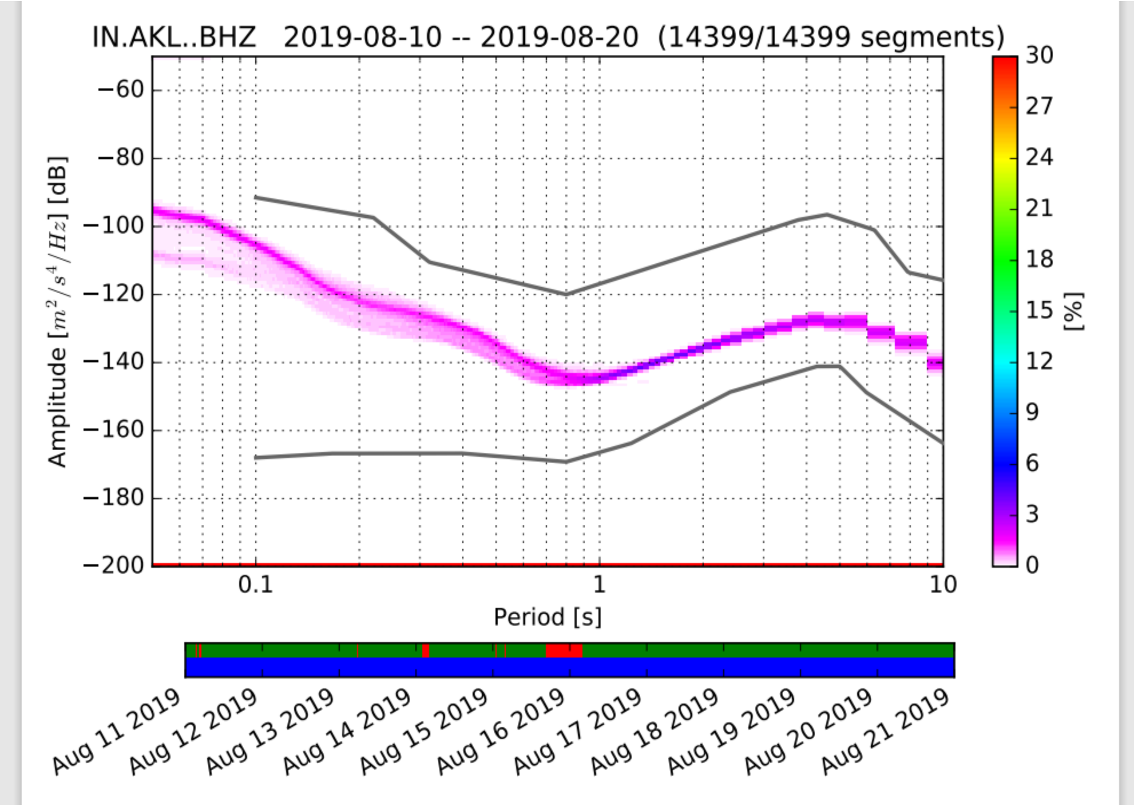

Figure 2 (b): PPSD analysis for Seismic Station at AKOLA (AKL) (11-21 August-2019)

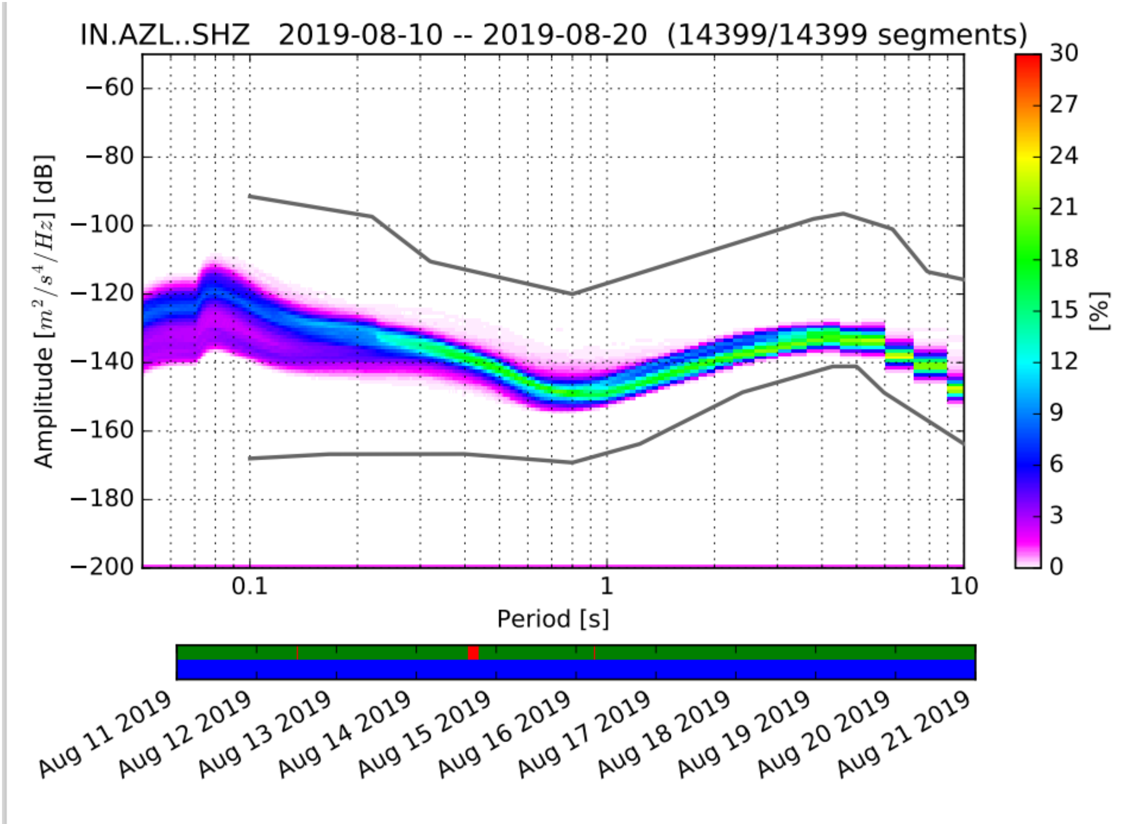

Figure 2 (c): PPSD analysis for Seismic Station at AIZAWAL (AZL) (11-21 August-2019)

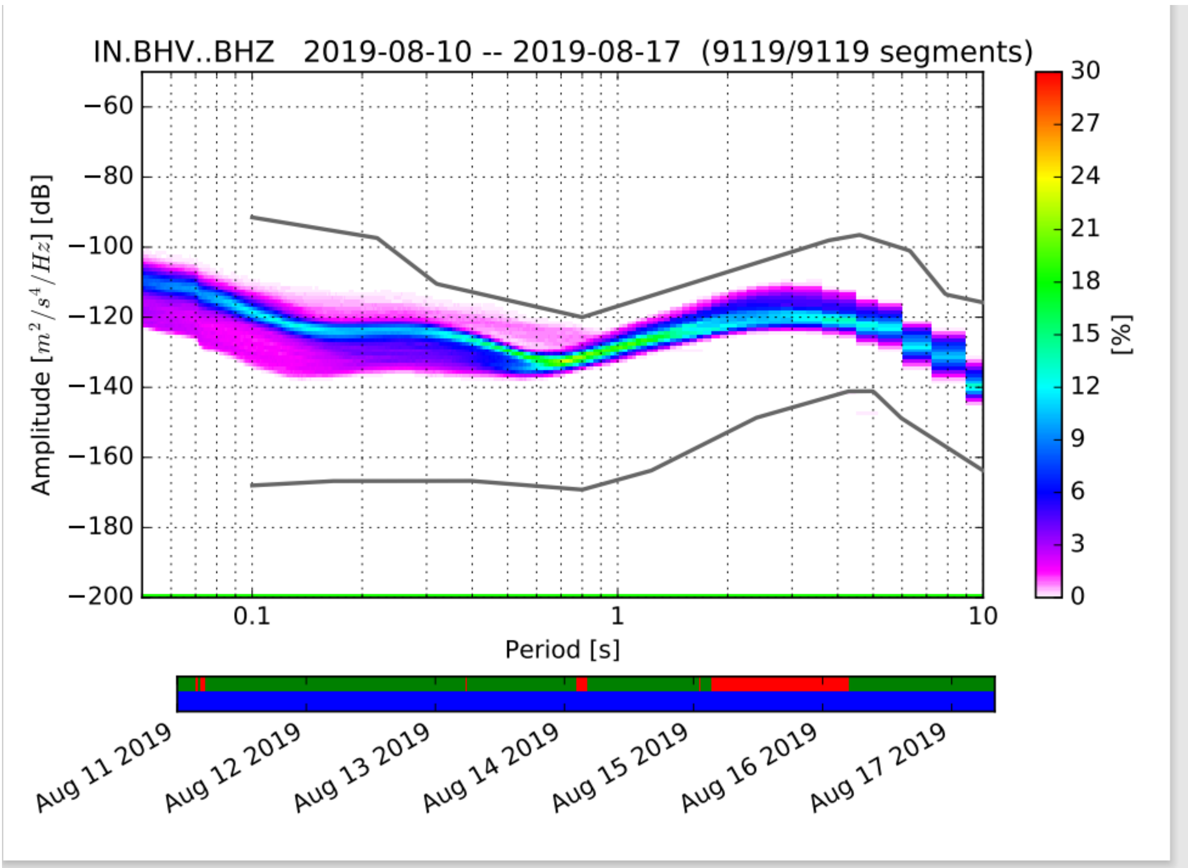

Figure 2 (d): PPSD analysis for Seismic Station at BHAVNAGAR (BHV) (11-17 August-2019).

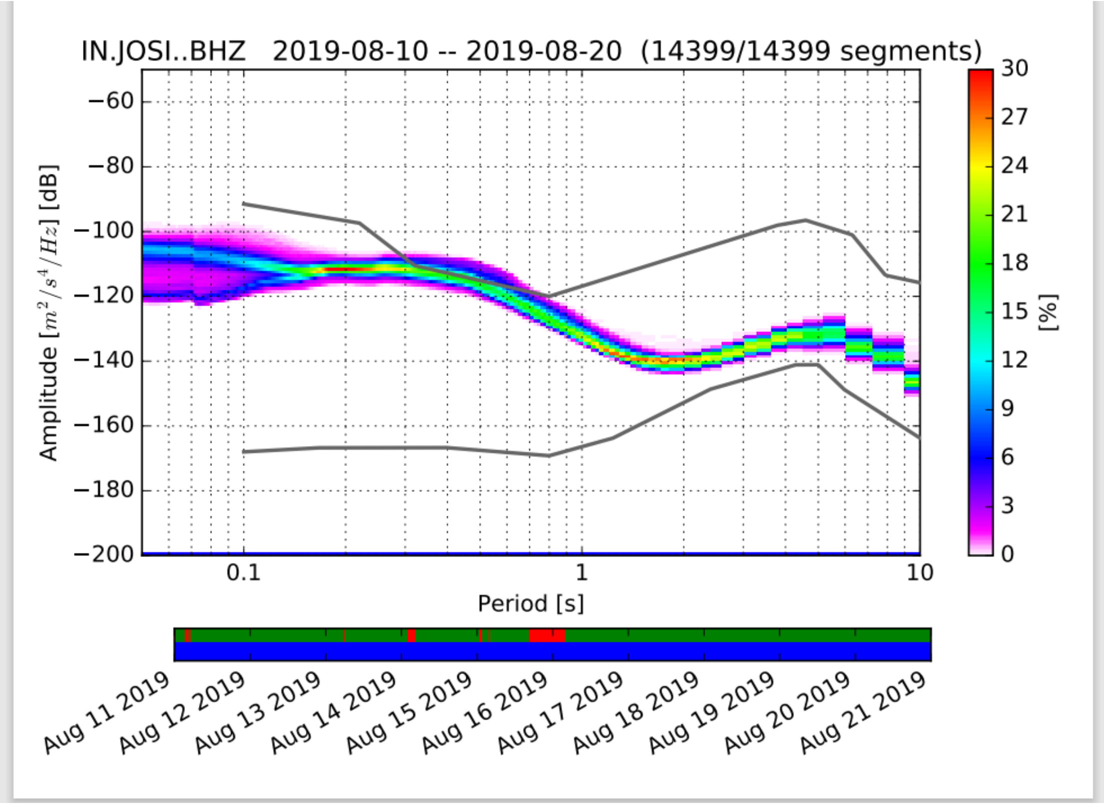

Figure 2 (e): PPSD analysis for Seismic Station at JOSIMATH (JOSI) (11-21 August-2019).

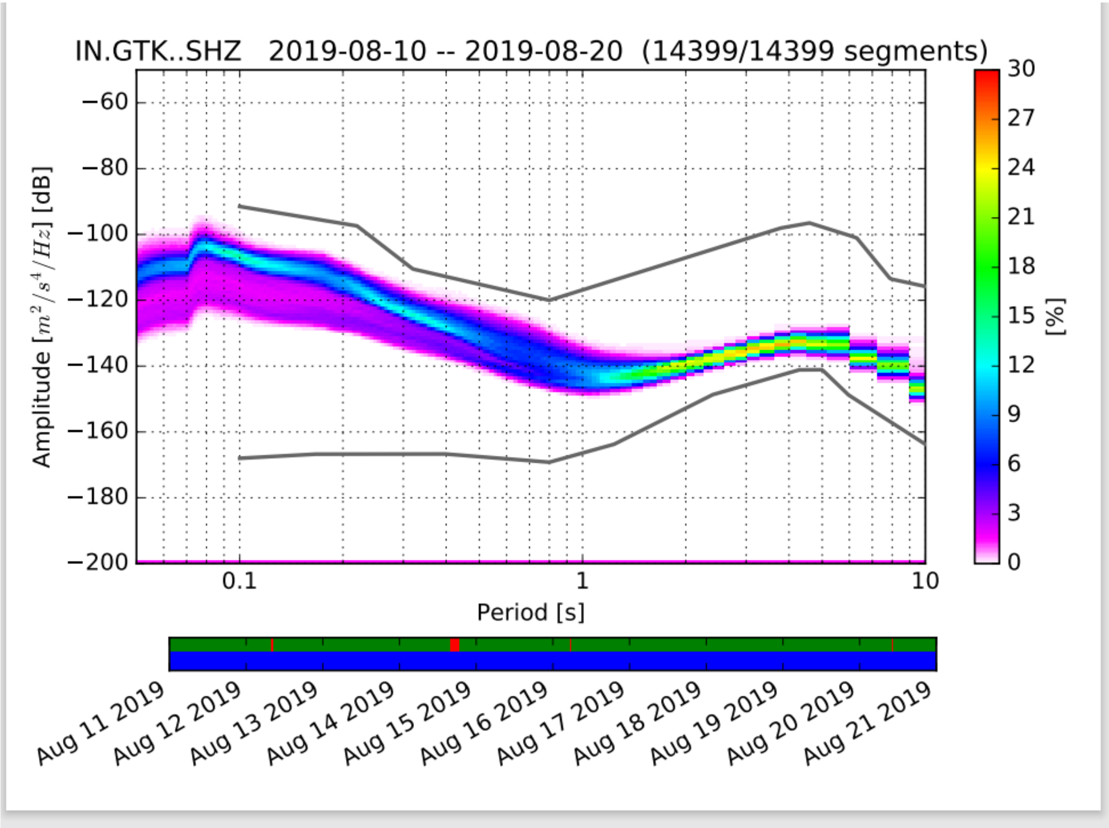

Figure 2 (f): PPSD analysis for Seismic Station at GTK (GANGTOK) (11-21 August-2019).

paper is very useful in diagnosing the seismic noise in digital seismic telemetric monitoring network and in determining the noise conditions in selected sites before establishing a countrywide seismic network of Indian domain. Future efforts have been made in developing an Earthquake Early Warning (EEW) System, to alert people once an earthquake occurs based on the arrival time of P-wave of the Earthquake.

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