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# Seismic noise characteristics of Maitri broadband seismic station in Antarctica: using power spectral density estimation

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***Abstract**: The seismic noise analysis is very useful tool for characterizing the performance of the existing seismic stations and it should be used as a first step in reducing the noise level in seismic signals. The main indicator of the quality of a seismic station is the level of the noise recorded in the absence of seismic signal. The level of noise recorded on seismometer can be reduced by locating the station away from human activity, selecting good geology and ensuring good seismic vault design and constructed at site, including thermal insulation and excellent ground coupling of broadband seismometer. In the year 1998 an ice free, rocky area on Schimacher Oasis was selected to build the Indian second research station "Maitri" (70°45'52" S and 11°44'03" E) in East Antarctica. The seismic background noise is studied at Maitri broadband seismic station operated in continuous mode till date. To access the performance of Maitri broadband seismic station and to investigate the characteristics of different types of noises dominated at site. The standard tool to analyse the noise performance is the power spectral density (PSD), where the frequency content of the waveform from a period is evaluated. The power spectral density and probability density function are calculated using seismic data from summer months period recorded at Maitri, Antarctica i.e. from January-February 2018 and compared with the winter month period i.e. September 2018. The data are in miniSEED format. The PSDs of seismic background noise are determine using seismic data free from earthquakes and instrument calibration/mass centring pulses [4]. The individual PSDs can be combined to produce a probability density function (PDF) for the PSDs.These PDF are a very powerful tool that can be used to rapidly evaluate the quality of seismic station. The power spectral density of ambient background noise is calculated and compared with the new global noise model. SQLX is unique seismological data analysis tool useful for both data quality control and research, follows the methodology of McNamara and Buland (2004). SQLX converts time-domain data into Power Spectral Density (PSD) equivalents in the frequency domain. PDF noise plots are useful for characterizing the current and past performance of existing broadband seismometer, for detecting operational problems within the recording system, and for evaluating the overall quality of data for particular station [9]. The background noise at site can also vary over time, as human activity in the vicinity can change and tracking the noise allows understanding the performance of the station through time. The result suggests that the noise levels of Maitri broadband seismic station are within the limit of the new global high and low noise model.*

***Keyword:** Seismic Noise Analysis, Maitri, human activity, Antarctica, Power Spectral Density (PSD), Probability Density Function (PDF).*

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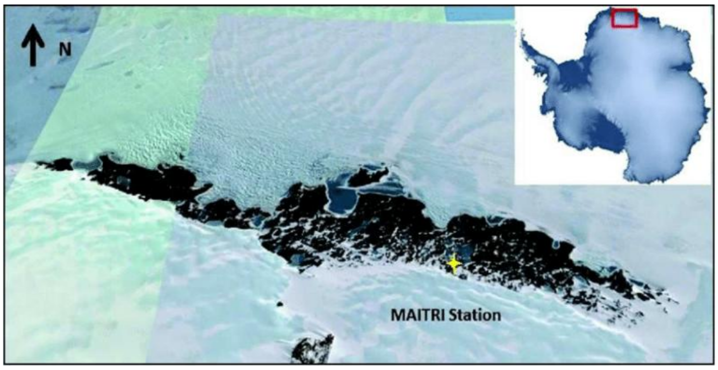
## I. Introduction

Antarctica is the world's greatest natural laboratory and attracts scientists for research. It is a stable platform for caring out scientific investigations. Being far away from all industrial areas remains an unpolluted region. The changes due to pollution all over the Globe can be monitored from here. Antarctica, the world's windiest, coldest and the stormiest continent has an area of 14 million sq. km. It is also called a pulsating continent as the size keeps on increasing and decreasing during different seasons. The continent starts freezing during winter i.e. for a month's start from March to October known as winter months in Antarctica, increasing the size to hundreds of km and the same starts breaking up as the summer approaches i.e. for months from late November to February months. It has one of the most hospitable terrains and harsh climate in the world. The 30 countries currently involved in research in the continent are authorized signatories of the Antarctic treaty, which is mandatory to operate research hubs in the continent. The population of the scientists operating in various research stations varies from 4000 during summer to a 1000 during the winter. CSIR-National Geophysical Research Institute (NGRI) with the support from ESSO-National Centre for Polar and Ocean research established a permanent seismic station was fully commissioned on 26th January, 1998 with analog and short period digital seismograph. This seismological observatory was further up-graded with the installation of broadband seismic station in January 2001 at the Indian base station Maitri, East Antarctica. This broadband seismic data was contributed to International Seismological Observatory (ISC), U.K for the preparation of worldwide global seismic bulletin. The paper describes the setup of digital broadband seismograph station, execution and data analysis using power spectral density. Using these PSDs, different types are created for analysis and inspection. For all data channels, SQLX provides statistics for the maximum and minimum noise levels across all frequencies[10]. Knowing the source of non-earthquake background noise at a given site can help in network design and provide insight into the physical phenomena responsible for noise. Determine the source of seismic noise generally relies on amplitude measurements [1]. Maitri is dedicated for conducting research on diverse disciplines including Earth Sciences , Glaciology, Atmospheric Science, Meterology , Geomagnetism, Biology, Oceanography, Communication, Medicine, Human physiology and Cold region engineering at the base camp. Data from the site were acquired in campaign mode every year during summer months start in Antarctica from late November – February.

## II. Description of site




Maitri (70°45’52” S,11°44’03E) is situated on the Rocky Mountains regions called Schirmacher Oasis as shown in Fig.1.The Schirmacher Oasis is situated on the Princess Astrid coast of Dronning Maud Land, Antarctica. This ice free land is spread across an area of about 34 $km^2$ between the coordinates 70°46’04”- 44’21” S and 11°49’54”- 26’03” E (Singh et al.,2012). It is inland station about 100 km from the shore at an elevation of about 50Meters above sea level

**Figure 1**: Schirmacher Oasis, Central Dronning Maud Landsite of Indian research station Maitri

## III. Installation of broadband seismograph

In extreme environments such as Polar region, carefully prepare all components of a seismic observation system even cables, tiny connectors, etc. for successful installation and operation since air temperature easily goes down to – 20 °C during the winter seasons. The enclosure room constructed with wooden materials of dimensions 8 m in length, 4 m in the width and 4 m in height as shown in figure2 (d). Which includes the installation of data acquisition system Reftek 130-01/3 (DAS), a 3 channel, 24-bit broadband seismic recorder? The DAS is a compact, lightweight, an LCD display, low power consumption system. The case is clamshell design, inherently waterproof, with access to all user features on the top of the unit. The LCD display allows the user to monitor the status of various sub system within the DAS without having a terminal device attached. The DAS has RAM pack mounted in the CPU board and the populated RAM capacity is 6 Mb. The digital data is written in the RAM initially. When it is 66% full, the data is dumped automatically into the compact flash card. It has operating voltage range from 10-16 VDC input and dynamic range of > 135 dB The seismic data recorded by DAS is locally stored in the compact flash card of 4 Gb. The DAS is powered by two batteries connected in parallel i.e.12V/100 AH and DC power supply to charge the battery and a GPS receiver is mounted on roof-top to get clear exposure to sky. It supplies time and position information serially to the DAS together with 1 Hz pulse. This encloser room is located 15 m away from the vault and is connected to the vault by a 2-inch plastic tube buried below the surface. This tube permits the seismometer cables of Guralp CMG-3T to pass through and connected to Reftek 130/01digitizer. Broadband seismometer consists of three-

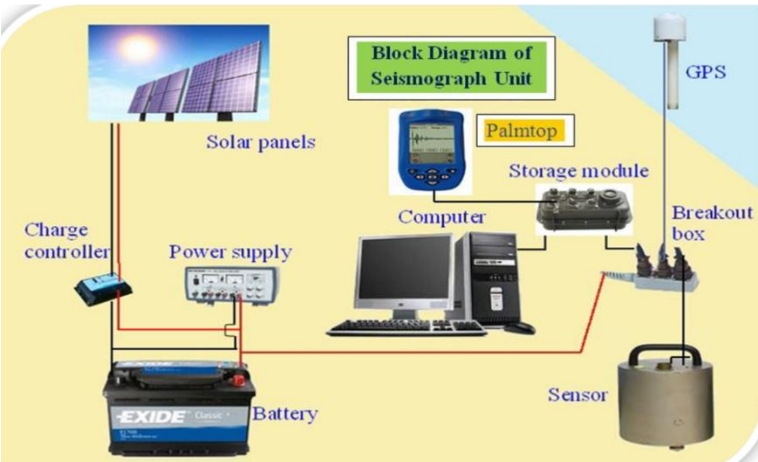



Figure 2: Block diagram of Seismograph setup at Maitri Station

component, force balance feedback type, featuring low noise and large dynamic range with a frequency bandwidth of 0.0083 Hz to 50 Hz, sensitivity of 2000V/m/s and power consumption of 1.3 Watt. It is sensitive to diurnal temperature variation and hence it will be enclosed with a thermal shield cover. The robust power system is one of the key elements to ensure the entire system surviving during its operation period year round for autonomous seismic station in the circumstances. Block diagram for complete seismograph installation shown in fig. 2[2].

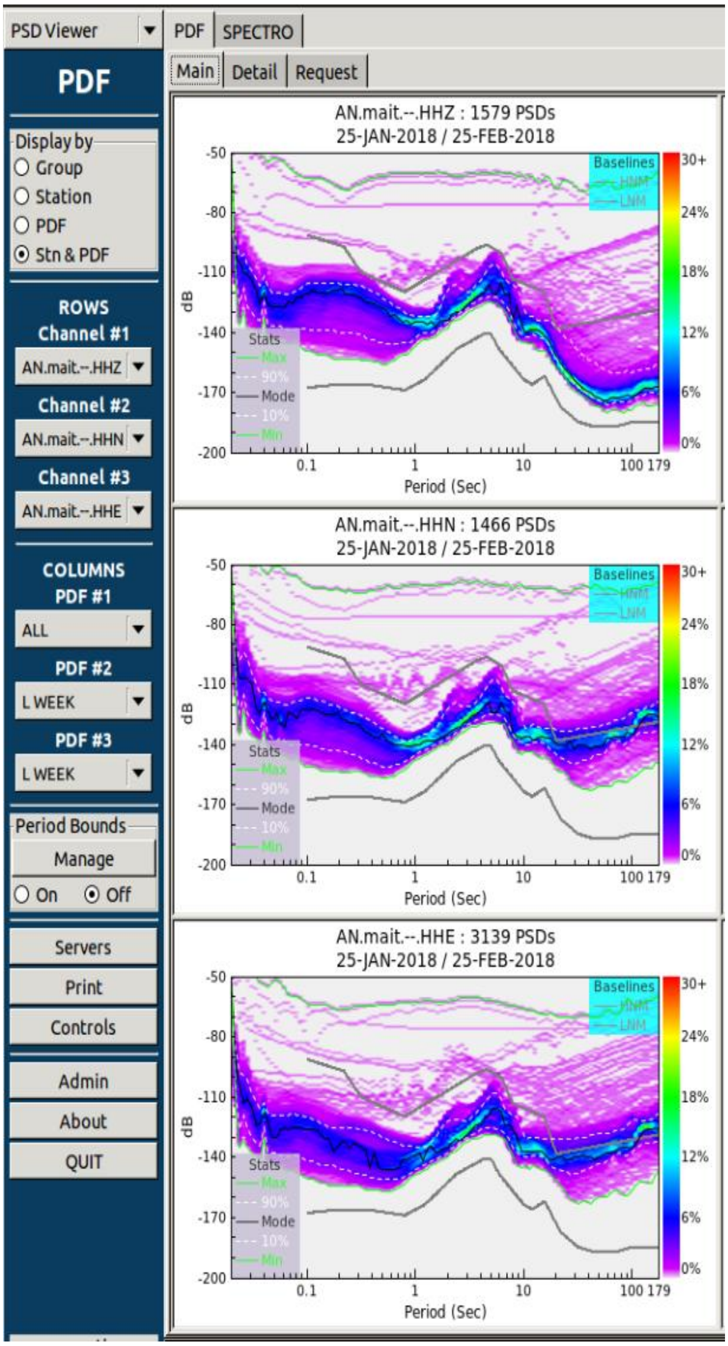
**Construction of seismic vault**

To have long term stability in monitoring of seismicity, stationary instrumentation scheme is used. Three channel digital broadband seismometer is installed in underground pit which is 2m (length) × 1m (weight) × 2m (height) The walls are made of thermally insulated materials was housed inside the pit. The construction of broadband seismic vaults as shown in fig.3.Inside centre of a underground pit a seismometer pier is constructed using concrete materials i.e. cement, sand and stone to construct 2 feet (length) × 2 feet (width) × 1 feet (height) from ground. A seismic vault provides adequate environmental conditions for the equipment, Ensures the proper mechanical contact of seismometer with bedrock. Ensures a suitable electric ground for sensitive electronic equipment. Provide sufficient space for easy access and maintenance of the instruments. Prevents large temperature fluctuations in the equipment due to day and night temperature differences or because of whether changes. Ensures adequate lightening protection. Prevents water, dust and dirt from entering the shelter.


Figure 3: (a) A photo taken during vault construction for broadband seismometer (b)Top view of seismic vault platform anchored to bedrock. (c) Installation of broadband seismometer (d) Photo of constructed enclosure room and seismic vault

## IV. NOISE POWER SPECTRAL DENSITY ESTIMATION

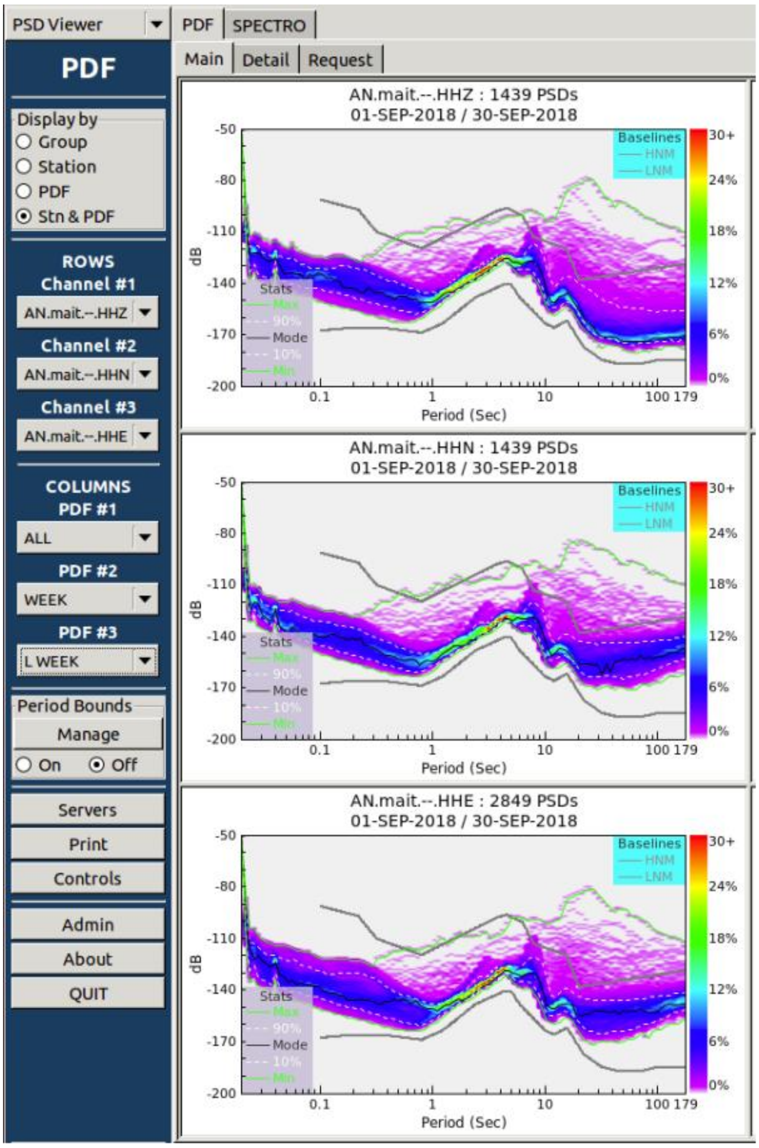
**Summer Periods:**




Summer seasons in Antarctica start from months late November to February. Maitri station HHZ vertical component as shown in fig. 4 have the amplitude ranging from -50 to -155 dB, with the PDF in the mean about 6-18 %. The segment sticks to middle of NLNM and NHNM, showing station have an average background noise. The median PSD is plotted solid black line as well as $10^{th}$ and $90^{th}$ percentile statistics white dashed lines are compared to the global high and low noise Peterson (1993).The highest peak of mean achieved during periods 5-10 seconds (0.2 - 0.1 Hz) and reached to lowest between 30 -100 seconds (0.03 - 0.01 Hz).Horizontal components HHN and HHE shows in figure 4 amplitude ranging from -50 to -155 dB, with the PDF in the mean about 6-18 %.The highest peak of mean achieved during periods 5-10 seconds (0.2 - 0.1 Hz).The segment stick to middle of NHNM and NLNM in periods range from 0.1 to 10 seconds and after that the segment stick closely to NHNM for periods from 10 -100 seconds. Horizontal components reveal the PSDs to be noisier than the vertical component by the sensitivity of the seismometers to the tilts (De Angeles 2008). The seismic noise spectrum has two main peaks, well recognized in Fig.4 recorded by the broadband seismometer CMG-3T. The longer period peaks 10-11 second is known as the single-frequency peak while the shorter period microseismic noise peak 4-8 second is readily observable called the double frequency peak. Cultural noise due to automobile traffic, machinery and other human activity generates a strong signal that can vary by 20 dB between day and night time and is observable in the PDFs at high frequencies (1-10 Hz, 0.1 - 1s).

Figure 4: Power Spectral Density and Probability Density Function of Maitri broadband seismic station correspond to summer period for all the components HHZ, HHN and HHE, both function is calculated using data from 025 Julian day (25 January, 2018) to 056 Julian day (25 February, 2018). The median PSD is plotted (solid black line) as well as $10^{th}$ and $90^{th}$ percentile statistics (dashed lines).

**Winter Periods:**




Winter periods in Antarctica start from March to October. It's a dark day without sun rise for eight months. Maitri broadband station HHZ (vertical component) as shown in fig.5 have amplitude ranging from -110 to -160 dB, with the PDF in the mean about 6 - 30%. The segment sticks closely to NLNM showing station have low background noise. The highest peak of the mean achieved during periods 6 - 10 seconds (0.16 - 0.1 Hz) and reached the lowest in periods 30 - 100 seconds (0.03- 0.01 Hz).Horizontal components HHN and HHE shows amplitude ranging from -83 to -165 dB, with the PDF in the mean about 6 - 30%.The segment stick closely to NLNM shows low background noise in the periods range from 0.3 - 20 seconds and stick in middle of NHNM and NLNM in periods range from 20- 100 seconds, revels that PSDs are more noisier than vertical component.

PSDs representation are well within the limits of the NLNM and NHNM.The short periods noise more precisely the cultural noise, seems to be predominant at the station, with the PSDs diverging towards the NHNM.The micro-seismic noise levels are low with the 10th percentile differing from the 90th percentile of the PSDs by ~20 db. Noise in the longer periods lies within the Peterson noise model, with the 10th percentile and 90th percentile deviating from each other by ~ 10 -15 dB

Figure 5: Power Spectral Density and Probability Density Function of Maitri broadband seismic station correspond to winter period for all three components HHZ, HHN and HHE, both function are calculated using data from 244 Julian day (01 September, 2018) to 273 Julian day (30 September, 2018).The median PSD is plotted (solid black line) as well as 10th and 90th percentile statistics (dashed lines).

**Summer day and night time comparisons:**

The effect of the cultural noise can be distinguished in studying the pattern of the PSDs distributions for HHE,HHN,and HHZ .PSDs analyses for spectral noise as shown in fig.6 (a) for the summer day time data and figure (b) for summer night time data, the PSDs are sampled using 1-hour segment from 06.00 to 11.00 day hours and summer night hours from 00.00 to 05.00 summer months i.e. 25th January - 25th February,2018.The PSDs plot shows considerable noise in the short period with the PSD distribution slightly near the NHNM in periods range from 0.2- 0.6 seconds. Micro-seismic noise is higher during the summer day time w.r.t to summer night time. The cultural noise during night time is lower than summer day time. Microseismic noise level with the 10th percentile differing from the 90th percentile of PSDs by ~ 10 - 30 db. Noise in the long period lies within the Peterson noise model with the 10th percentile and 90th percentile deviating from each other by ~ 5 - 10 dB.A high ratio show the background noise in day time was higher than the night time in specific ranges of short period, especially for the period lower than 1 second i.e.(1-10 Hz, 0.1-1s). It is mostly caused by human activity. It will disturb seismic recording at day time and also reduce signal to noise ratio (SNR).The gray lines in (a) and (b) indicate the New High Noise Model and the New Low Noise Model introduced by Peterson et al. (1993) with 10th and 90th percentile statistics (dashed lines) along with the mode of the PSDs values.

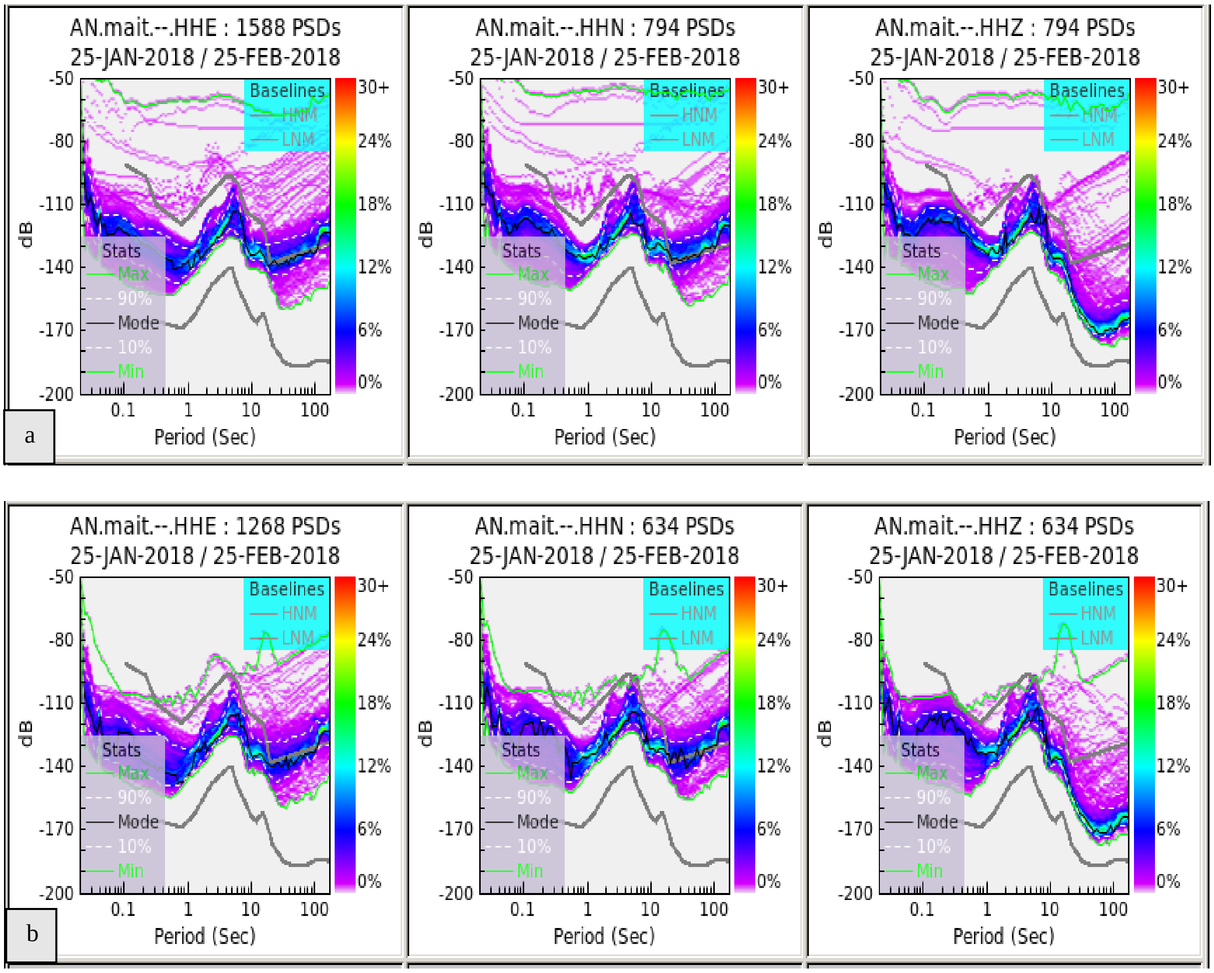



**Figure 6:** Power Spectral Density and Probability Density Function of Maitri broadband seismic station correspond to all three components HHE, HHN and HHZ (a) summer period day hours (b) summer period night hours.

**Winter day and night comparisons:**

PSDs analysed for spectral noise as shown in fig.7 for winter day and night hour's data. For the day time, the PSDs are sampled using 1-hours segment data from 06.00 to 11.00 hours and for night time from 00.00 to 05.00 hours i.e. data periods from 01st September -30th September, 2018 used for PSDs analysis. In the microseismic zone, noise is almost same during winter day/night time hours. There is approximately of 4-8 dB variation between the 10th and the 90th percentile of the PSDs in the microseismic zone, while long period noise have wide variation in PSD between 10th and 90th percentile by ~ 10 -20 dB. The gray lines in (a) and (b) indicate the New High Noise Model and the New Low Noise Model introduced by Peterson et al. (1993) with 10th and 90th percentile statistics (dashed lines) along with the mode of the PSDs values.

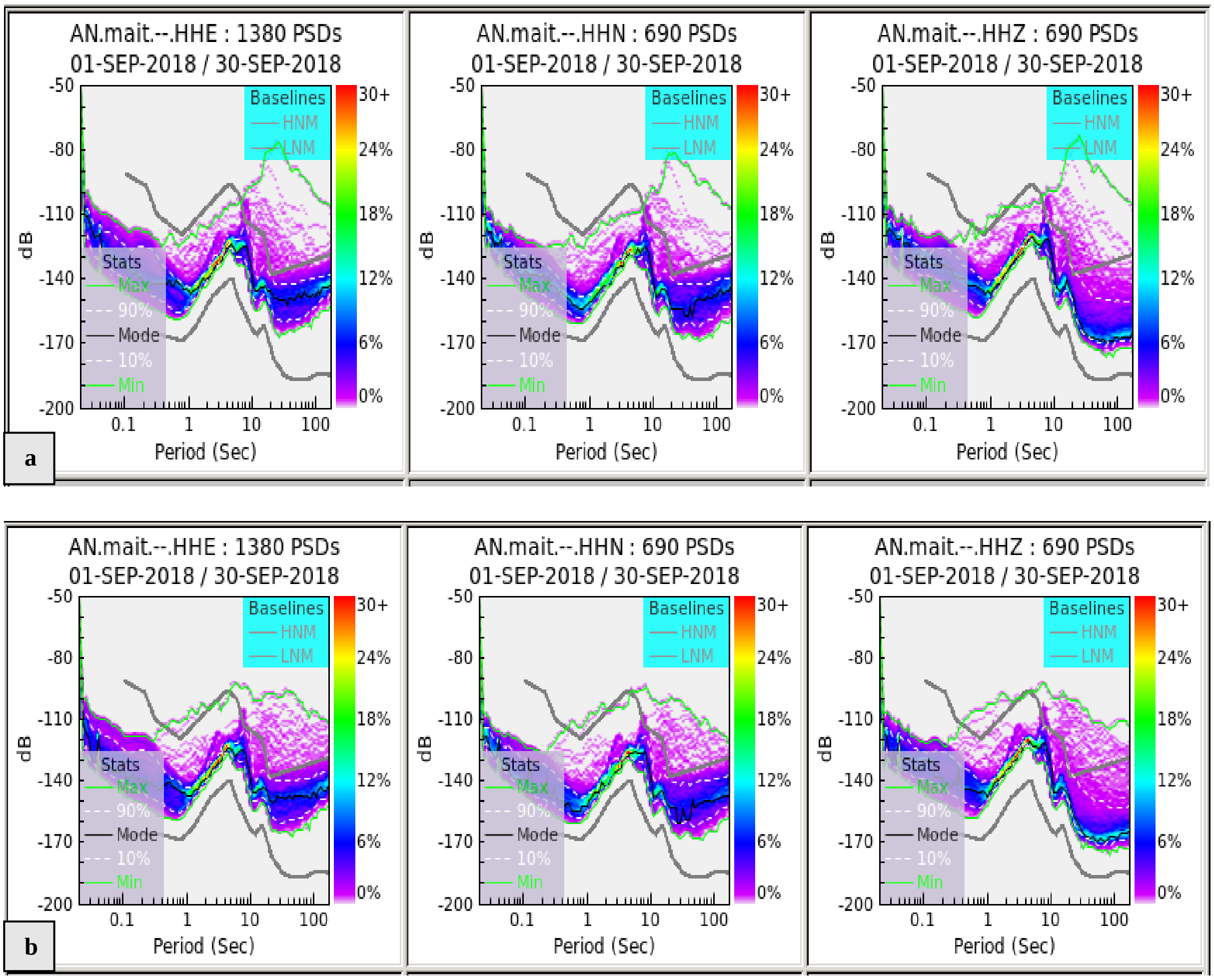



Figure 7: Power Spectral Density and Probability Density Function of Maitri broadband seismic station correspond to all three components HHE, HHN and HHZ (a) winter period day hours (b) winter period night hours.

## V. Background Noise

A powerful method was introduced by Aster et al., 2008 and McNamara and Buland 2004 to conduct background noise analysis to evaluate station performance and to examine the evolution of seismic noise, which facilitates estimating the power spectral density (PSD) and then we construct probability density function (PDF) to investigate the highest probability noise level for each channel as a function of period [7]. Another useful feature of the method at an operational point of view is that it enables us to check if the system response is written correctly, which is quit important to maintain seismic station. Fig.8 shows plots for PDF (MAITRI) for the month of January-February 2018 (upper left; vertical component, recorded time traces used for PSD calculation (upper right), their corresponding PSDs (bottom left) and start times (bottom right) [8]. The great earthquake Papua New Guinea, Indonesia of Mw 7.5 occurred on February 25$^{th}$, 2018, and the largest earthquake instrumentally recorded in the Papuan Fold Belt since 1900.This destructive earthquake caused more than 125deaths, injured more than 500, as reported by the U.S Geological Survey (USGS). Total damage to buildings, infrastructure, sinkholes and landslides followed by few aftershocks of Mw 6.7, 6.5 and 6.0 on March 04$^{th}$, 05th and 06$^{th}$, 2018. Which energy was dominated at a low frequency range (inside of a rectangular box, upper left of fig.8), it doesn't affect significantly the PDF since it happens much less frequent than any other signals or noise. Trace viewer split screen tab in fig.9 displaying three-component seismograms at Maitri station for the Papua New Guinea, Indonesia earthquake, a magnified portion, and the spectral transformation of this magnified portion. Prior to transform, the selection is demeaned and tapered with a 10% cosine filter. The FFTs are presented with the amplitude axis to the left of the transformation, period axis at the top of the transforms and frequency axis at the bottom of the transforms.

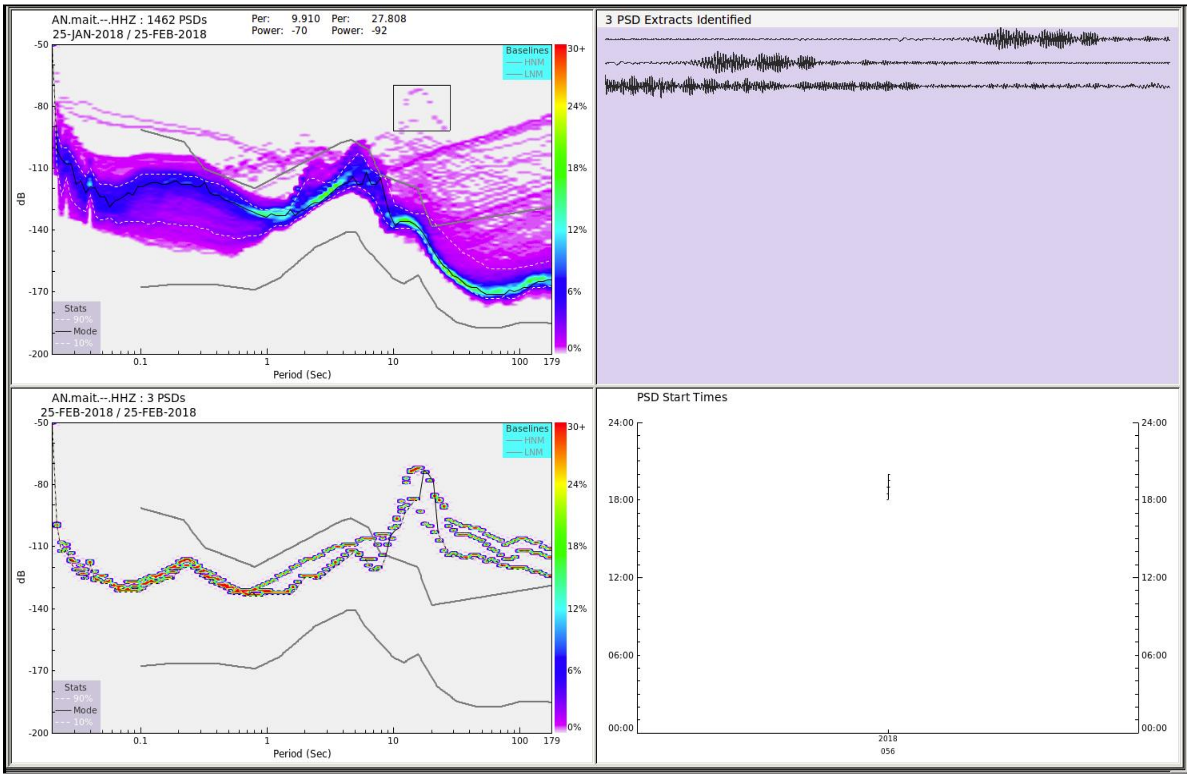



**Figure 8:** The PDF plot for the month of February-March 2018(01/25 ~ 02/25; MAIT). The upper left displays system PDF with a sub-select bounding box. The lower left panel shows the resultant PDF of PSDs interesting the bounding box defined between periods of 9.910 to 27.808 seconds, and -70 to -92 dB (Papua New Guinea, Indonesia earthquake of Mw 7.5 on 25 Feb 2018). The lower right panel is histogram displaying the start times of the interesting PSDs.The upper right panel displays the source traces for the interesting PSDs [8].

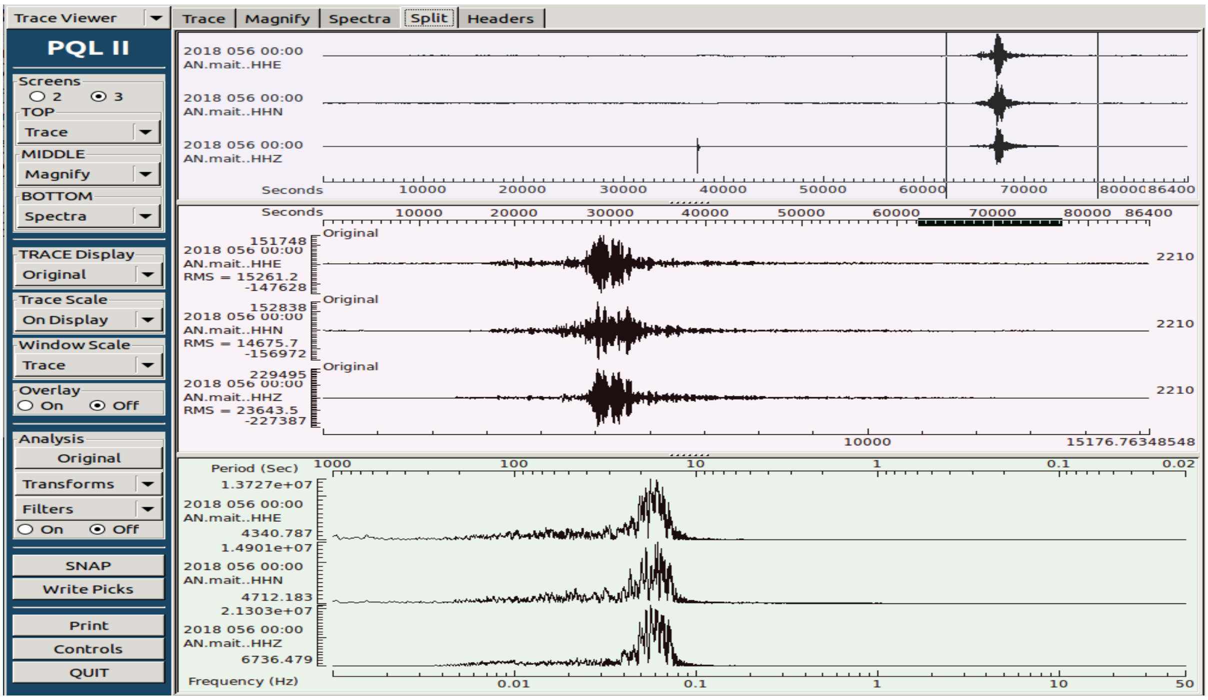



**Figure 9:** A trace viewer split screen tab displaying three complete traces for Papua New Guinea, Indonesia earthquake of Mw 7.5 on 25 Feb 2018, a magnified portion of earthquake and the spectral transformation of this modified portion.

The PDF plot for the month of September 2018 as shown in fig.10. The upper left displays system PDF with a sub-select bounding box. The lower left panel shows the resultant PDF of PSDs interesting the bounding box defined between periods of 6.992 to 9.082 seconds, and -94 to -103 dB (Fiji Island earthquake of major Mw 7.8 on 06th Sept,2018 and East of South Sandwich Islands earthquake of moderate Mag 5.7 on 27th Sept ,2018). The lower right panel is histogram displaying the start times of the interesting PSDs.The upper right panel displays the source traces for the interesting PSDs.

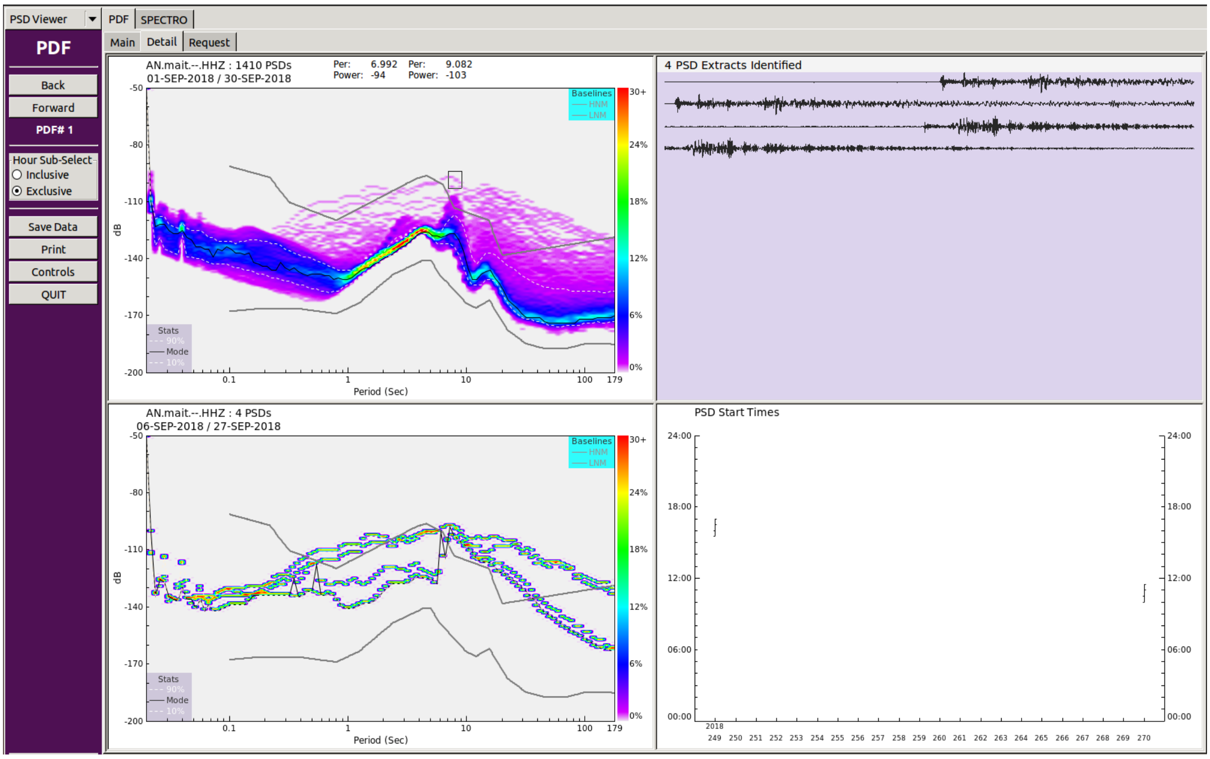



**Figure 10:**The PDF plot for the month of September 2018(09/01 ~ 09/30; MAIT).

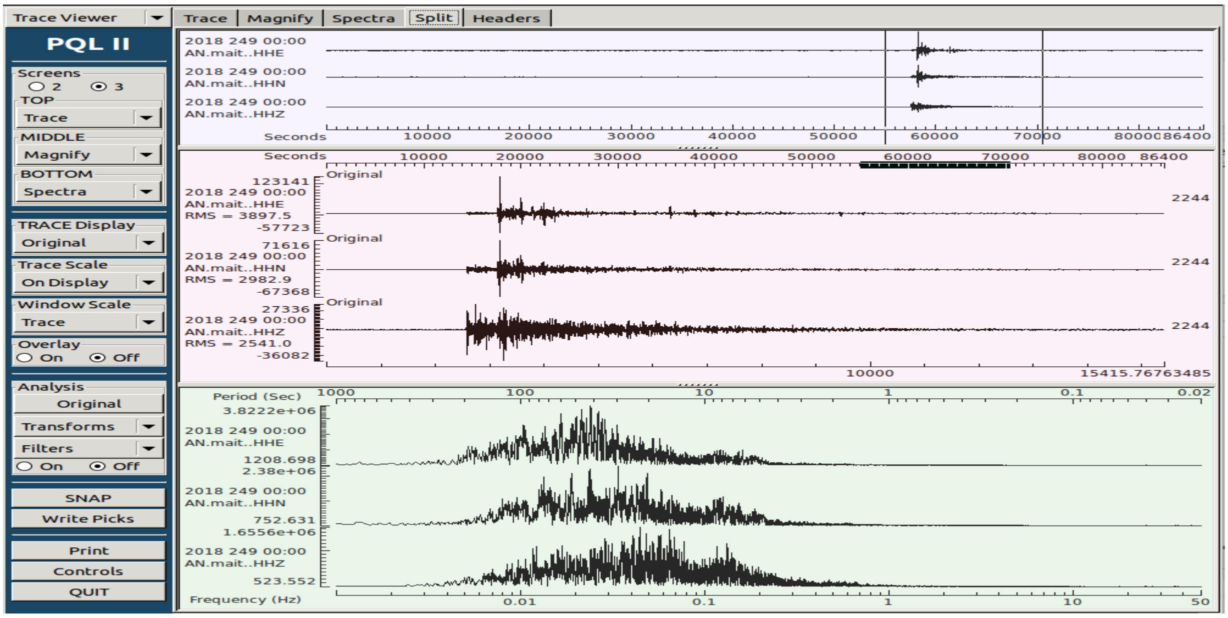



**Figure 11:** A trace viewer split screen tab displaying three complete traces for Fiji Island earthquake of major Mw 7.8 on 06th September,2018, a magnified portion of earthquake and the spectral transformation of this magnified portion.

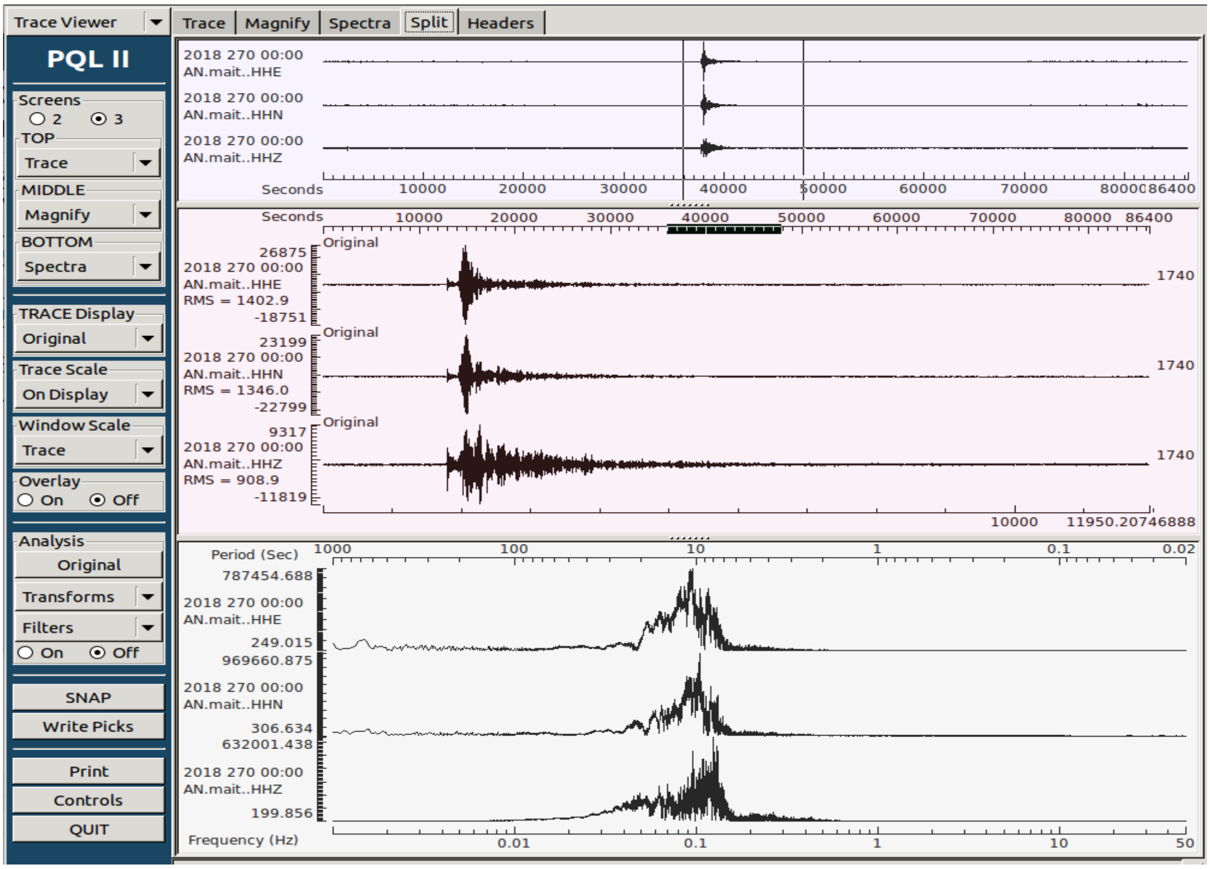



**Figure 12:** A trace viewer split screen tab displaying three complete traces for East of South Sandwich Islands earthquake of moderate Mag 5.7 on 27 September ,2018, a magnified portion of earthquake and the spectral transformation of this modified portion.

## VI. Conclusions

Analysis of spectral response to determine the level of background noise in the seismic station by using the Power Spectral Density and Probability of Density function from the station spectral result. We determine the background noises level according the New Low Noise Model and New High Noise Model that suggested by Patterson (1993).It has been observed that variation in noise levels during summer and winter periods in short period range is 5 to 10 dB lower at winter.PSDs to be noisier than the vertical component by the sensitivity of the seismometers to the tilts. Due to tilts, the gravity effect is coupled to the horizontal components while they are not in the vertical component (De Angeles 2008).The software SQLX used to determine power spectral density function of the background noise and evaluates the probability density function.So the levels of the ambient seismic noise as well as the full range of the factors influencing the quality of the data and the performance of a seismic station are analyzed.The result of spectral analysis indicates that Maitri broadband seismic station has the lowest background noise level in winter months as compared to summer months, so it has highest signal to Noise Ratio (SNR).Summer and winter periods of seismic data compared with day and night variations in studies divulge that day time registers more noise  compare to night time especially in summer months and their not that much effects in background noise level in winter day and night studies. This good quality of recording signal because the seismometer located on the especially designed seismic vault and the site is protected from the ambient or environmental noise. The study shows that the Maitri seismic station are situated at most appropriate sites and PSD falls within NLNM and NHLM for Maitri seismic station situated in East Antarctica.

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