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Quality Control and Assessment Noise Levels Detection for Aswan sub-network of the Egyptian National Seismic Network (ENSN)

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Abstract: Understanding the description of circumstantial seismic noise in seismic network is very important mission for inspection the detectability presentation of recording seismic centers. Egyptian National Seismic Network (ENSN) was constructed following the Cairo earthquake which happened in Egypt at 12 October 12, 1992. The current paper focuses on the results of background seismic noise assessment and station performance of twelve broad band seismic stations of Aswan sub-network installed around Lake Naser in Aswan zone in the south of Egypt. We apply anew detection approach for this purpose using the PQLX package which depends mainly on the computation of probability density function (PDF) and power spectral density (PSD) for speculating the surroundings sound levels, for the periods between ~ 0.02 and 180s. The analysis covered the available data during one year of continuous recording of the seismic results. The obtained data demonstrated that some centers have extremely little detectability and altitude of noise was elevated in some frequency bands which influence the seismic actions recording. Whereas the other stations demonstrate best presentation. We produced noise maps to evaluate noise characteristics of Aswan sub-network of the ENSN for different periods to assess the origin of the noise. We also determined the effect of the high dam turbines in seismic data at a frequency of 2 Hz. The yield from this work is valuable for estimating the operational obstacles in the southern branch of the ENSN and will be pertinent to the future sitting of the ENSN centers.

[Ramdan Desouky, Abd El-Aziz Khairy Abd El-Aal, Mohamed Sherief Moustafa, Mohamed Moawad. **Quality Control and Assessment Noise Levels Detection for Aswan sub-network of the Egyptian National Seismic Network (ENSN).** *J Am Sci* 2020;16(3):90-105]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 11. doi:10.7537/marsjas160320.11.

Keywords: Background seismic noise, Seismic detectability, power spectral density (PSD), ENSN.

1. Introduction

The main task of any seismic network is to monitor and detect earthquakes at teleseismic, regional and local distance and also to record the small seismic events resulting from different seismic sources. Basically, the analysis and processing of seismic data using many different approaches need High-quality data with different frequency ranges. Evaluation of seismic noise level resultant from other disturbant factors other than earthquakes can be done by applying the probability density function (PDF) calculated from the power spectral density (PSD) of the ambient sounds at any seismic station (McNamara and Buland 2004). Generally, the origins of seismic noise comprises, traffic noise, turbulent wind, tides, sea waves striking the coast, machinery, and culture-based noises (Boonefoy-Claudet et al., 2006).

Many researchers have studied the nature and characteristics of seismic noise recorded by seismic stations for long time (e.g. Longuet-Higgins1950; Brune and Oliver 1959; Franti et al. 1962; Peterson, 1993; Fix 1972; Stutzman et al. 2000; Tanimoto 2005).

Ambient noise was classified by Peterson (1993) and this classification is used as a reference in the noise seismology field till date. In this work, the seismic noise on a large area of the globe and calculated PSD of recording data of all stations. He developed two novel models, low- and high-noise models (NLNM & NHNM, respectively). Some authors established a classification for measurement of background seismic noise (McNamara and Buland, 2004). Fundamentally, they calculated power spectral density (PDSs) from data collected from many seismic stations across the continental and United States (US) and they evaluated PDFs. The new noise model of McNamara and Buland (2004) not depends the low-noise floor level of Peterson (1993), but based on the probability noise and it is called “Mode Low-Noise Model” (MLNM).

The Egyptian National Seismic Network was installed after the strongest 1992 Cairo earthquake which caused massive destruction of infrastructure and loss lives. It started process at the year 1997 with approximately 30 various kinds of seismic sensors for measurement of the earthquake motion inside and around Egypt. Nationally, many Egyptian researchers have studied the characteristics and origin of seismic noise at some permanent and temporary Egyptian seismic stations (e.g. Faried, 2013, Abd el-aal and Soliman, 2013; Abd el al., 2013, 2019).

The goal of the present investigation is to reconsider the data quality and performance of Aswan sub-network stations in southern Egypt after earlier labors performed by many Egyptian authors (e.g. Abd El-Aal,2013; Faried,2013 and Abd el-aal and Soliman,2013. To continue the previous works, this manuscript comes to provide good results with a good contribution to a large extent in the knowledge and solving the problems of recording of the small earthquakes in and around High Dam and Lake Naser in Aswan region. the High Dam is one of the largest construction facilities in Egypt during the twentieth century and affects millions of Egyptians.

2. Methodology

In the present study, our main target is to investigate data quality, station performance and the characteristics of ambient noise of twelve broadband stations of Aswan sub-network distributed around Lake Naser in southern Egypt in Aswan area (Fig.1). The parameters of the deliberate stations comprising locations, sensor type, and kind of rock or soil beneath stations are illustrated in Table (1). the analysis technique of McNamara and Buland, 2004 was applied to calculate the probability density function (PDF) and the power spectral density (PSD).

Table (1). Station parameters of Aswan sub-network of the Egyptian National Seismic Network (ENSN).

SN	station code	latitude	longitude	sensor name	sample rate
1	BRNS	23.8559	34.1143	TRILLIUM_240	100 sample / second
2	KSR	23.6105	33.0872	Trillium-40	100 sample / second
3	MABD	22.9726	32.3258	Trillium-240	100 sample / second
4	NAHD	23.8022	32.778	Trillium-40	100 sample / second
5	NGMR	23.52169	32.40756	Trillium-40	100 sample / second
6	NKUR	24.0042	32.6514	Trillium-40	100 sample / second
7	NMAN	23.9169	33.0749	Trillium-40	100 sample / second
8	NWKL	23.41309	32.44888	Trillium-40	100 sample / second
9	NEDF	24.888	32.947	Trillium-120Q	100 sample / second
10	NNAL	23.2931	32.6647	Trillium-40	100 sample / second
11	NSKD	23.661	32.386	Trillium-40	100 sample / second
12	NNMR	23.7376	32.5618	Trillium-40	100 sample / second

2.1- Power Spectral Density

The direct Fourier transform or Cooley-Tukey method are applied as a general method to obtain PSD for the data obtained from the stationary random seismic knowledge (Cooley and Tukey, 1965). The technique calculates the PSD of the original data through a finite-range fast Fourier transform (FFT) and regarding the calculation competence it considered more efficient than other methods.

The following equation are used for calculation of the finite-range Fourier transform of a intermittent time sequence y (t):

$$Y(f, T) = \int_0^{Tr} y(t) e^{-i2\pi ft} dt - \quad (1)$$

where the number of frequency amplitude estimates *nfft=(N/2)+1=16385*. For discrete frequency values, f_k, the Fourier components are defined as:

$$Yk = \frac{Y(f}{\Delta} \quad (2)$$

For, $f_k = k/N \bullet t$ *when* $k = 1, 2, \ldots, N-1$.

Hence, using the Fourier components defined above, the total power spectral density estimate is defined as:

$$Pk = \frac{2\Delta t}{N} |Yk|^2$$

2.2 Probability Density Functions

After the estimation of PSD we also generate PDFs of the PSDs obtained By:

$P(T_c) = N_{PTc}/N_{Tc}$

Where N_{PTc} is the number of spectral estimates that fall into a 1 dB power bin, P, with a range from –200 to –80 dB, and a center period, T_c. N_{Tc} is the total number of spectral estimates over all powers with a center period, Tc. By this approach, will assist in diminishing the unfairness information entered into study of the Earth's composition from mistaken suppositions concerning the character of seismic noise that leads to variations in detection of earthquake. The noise model is determined as a quantitative and graphical illustration of the highest and lowest vertical seismic noise levels noticed globally and are tremendously valuable as a indication for site or quality of instrument (Peterson, 1993). Peterson, 1993 designed a model for estimation of noise are called noise curves which introduce in the calculation both the lower and upper margins of the accumulated set of the delegate ground hastening power spectral densities estimated for either quiet or noisy intervals of the globally digital designed stations (Havscov and Alguacil, 2002). By using the Peterson New Model limits, the noise levels are contained at all stations. In the present investigation we used the PQLX (PASSCAL Quick Look Extended) software. Through this software, from the Power Spectral Densities (PSD) we can calculate the probability density function (PDF), which enhances the user to entrance precise time intervals of PSDs (PDF subsets). The benefit of the technique represented in no is that, there is no necessitate to get rid of any knowledge from any temporary system, general data artifacts, or earthquakes, for the reason that they plot into a probability level in the background. Integrating the data obtained from the present work with the previous data from the study of Abdel Hafiez, 2015, an entire outline can be obtained regarding the possibility for detection of the Egyptian seismological network.

3. Data set and network

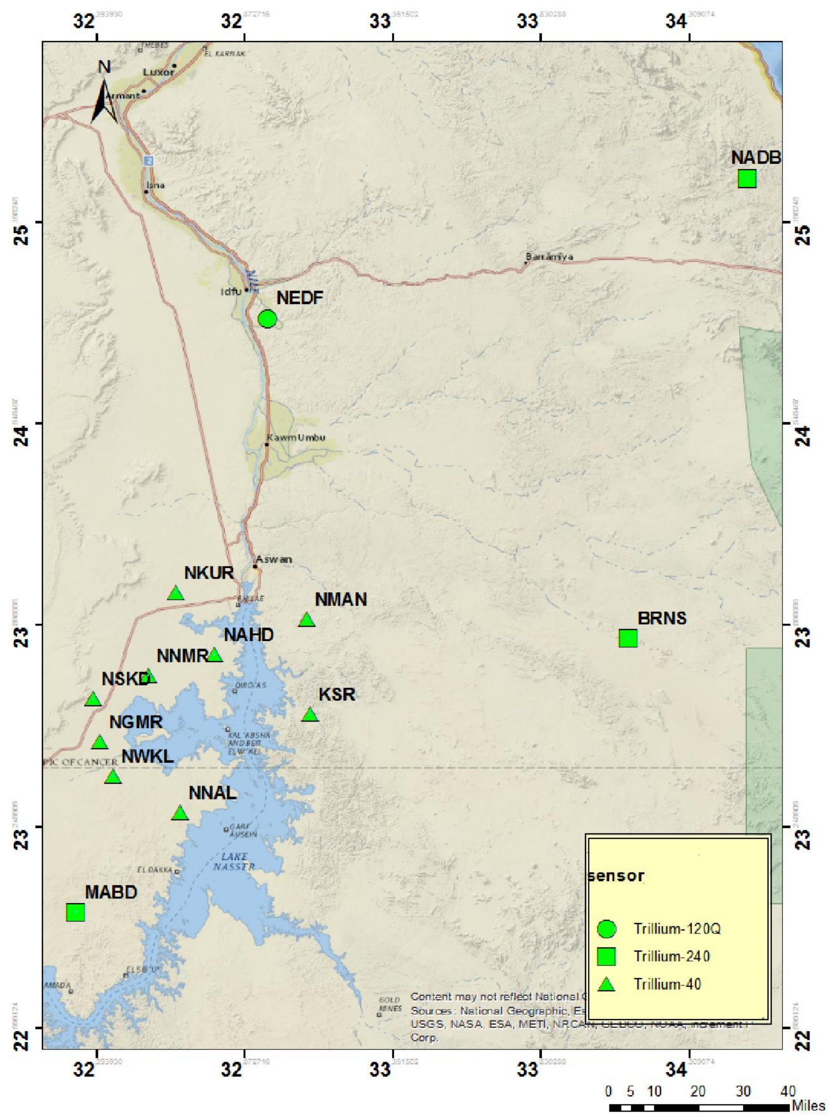

Figure 1.: Aswan sub-network of the Egypt broadband stations; the stations with green triangles, Green circles and green box are equipped with Trillium -40 Seismometers, trillium- 120Q seismometers and trillium

The ENSNseismic network includes about 31 broadband and 19 short period stations distributed across of Egypt. The network also includes one main center located at Helwan town (Cairo city) and five sub-centers located at Aswan, Marsa Alam, Hurghada, Kharga, and Burg El-Arab cites. Geographically, The ENSN was divided to six sub-networks as the following:

1- Cairo sub-network stations (MYD-HAG – KOT – NAT- TAMR – RYAN-NBNS-RYAN).

2- N-coastsub-network stations (MATC-DB3-SWA-SLM).

3- Aswan sub-network stations (KFR-SHG-MSM-NQEN-BRNS-KSR-MABD-NGMR-NEDF-NKUR-NMAN-NNAL-NNMR-NSKD-NWKL-).

4- Red Sea sub-network stations (HRG-ZAF-NSFG-NQSR-NMRS-AGS-NADB-GRB-SUZ).

5- N-VALLEY stations (FRF-SUT-DK1-GTR-KRG-PRS)

6- Sinai Stations (KAT-NUB-DHB-TR1-TR2-RDS-BST-ZNM)

The continuous seismic noise data from 12 broadband seismic stations in Aswan sub-network located in the southern part of Egypt during the year 2017 is used in this study (Fig. 1). Nine of these stations are equipped by trillium – 40 sensors, and three stations are equipped by trillium– 240 sensors while the trillium -120-Q sensor was installed in one station. Basically, the response file for each sensor type is different from the others. The seismic data extracted from all these stations were mainly sampled with sample rate 100 s/s. These stations are installed in hard outcrops and the data is received online at the main center in Helwan and sub-center in Aswan.

4. Data processing and analysis

We collected seismic noise data from the studied stations within the time period from 1 Jan 2017 to 31 Des 2017 in Nanometrics' format then we converted the data to MiniSEED (WWW.iris.com) format which is suitable for analysis using the software PQLX. First, the noise data per day from each channel in each studied station is accumulated, and converted to MiniSEED format from the stored data unit through the software Apollo Project. Second, we used the software RDSEED (WWW.iris.com) to obtain a response file for each channel which contains information about the stations as follows:

- Channel response data (Station Name, Network Name, station location, channel type start time and ending time).
- Response (Transfer function).
- The "RESP" file represents the velocity response.
- The "Sensitivity" at the end of the "RESP" file is the product of all the gains in the file.

In order to obtain the response file for each channel, we extracted a sample of the data by the Atlas Data Analysis software, stored it in the SEED data format and extracted the response file by RDSEED program as shown in Figure 2.

The PQLX software package was used to calculate the power spectral density (PSD) (McNamara and Boaz 2005) and background noise spectra for 12 broadband stations of Aswan sub-network in the frequency range between 0.005 Hz to 50Hz (0.02 and 180 s.) In PQLX program, the continuous data were divided into 1- hour segments and each one hour was divided into 13 segments with 75 % overlapping to reduce the variance and 50 % overlapping for1- hour segments. Mean and linear trend were removed from the data and then we applied tapering process. Subsequently, the instrument response was removed by DE convolution of instrumental response. Finally the Fast Fourier Transform (FFT) is performing. For each one hour segment an average PSD in units of (m/s2)2/Hz was calculated.

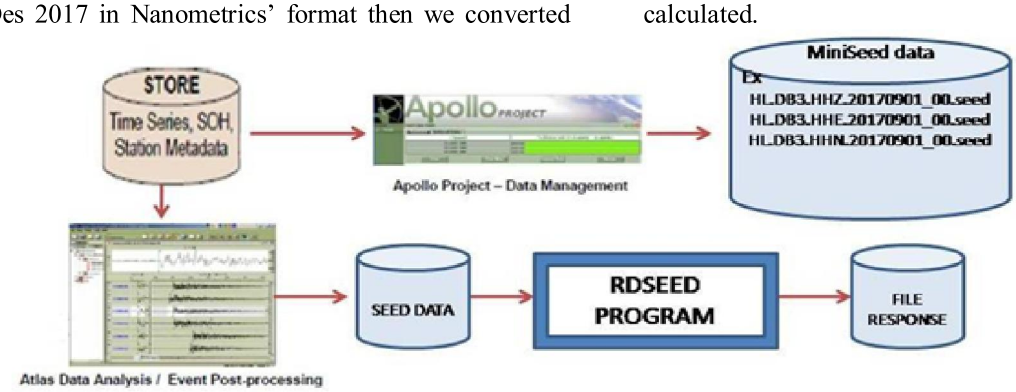

Figure 2.: Data preparation Data processing flow chart

5. Results and Discussion

5.1. Background noise characterizations

Figures3a, 3b and 3c show the power probability distribution, mode, median and mean for the noise level of the studied stations in Aswan area. The figure illustrates power probability distribution for the noise level, which consists of color bar representing the probability of occurrence of each PSD. This probability, ranging from 0% to 30%, where The light purple color indicates that the probability ranged from (1–2%), and when the power of probability is increased near red color which indicates that high-power probability greater than (>30%) in the noise PDFs. We obtained the type noise curves (Fig. 4) for all stations, since they represent the highest probability power for given periods. he Aswan region which includes the stations is fundamentally affected by many types of noise sources (e. g. cultural noise, high dame turbines and quarry blasting). In Aswan area, the differences in the day/night cultural noise are depending on the distance of the place from towns, farms, roads, buildings and industrial plants that are less active during nighttime.

5.2. Day and night variation

In order to show the cultural noise variation, we studied the difference between the day and night recorders. the data from the time period 06:00 am to 6:00 pm was to represent the daytime and from 6:00 PM to 6:00 AM which represent the nighttime (Fig 5), then the PDF modes are obtained for these records for all stations as shown in Figure 6a, 6b, and 6c. The PSD values of the level of noise during the night time is lesser than at the higher frequency more than1Hz matched to that in the daytime. Diurnal variation in the higher frequency bands is very clear in most of the stations where some of these stations are located very close roads (e. g. NKUR, NSKD, BRNS and NGMR). Other stations contain Diurnal variation due to the bad thermal isolation and this is clear in lower frequency band (NEDF, MABD and NNMR). According to the obtained results, we detected that there are many types of noise sources in Aswan area which clearly affect most of the stations, thus some of the small seismic events cannot be recorded clearly on during the day.

5.3. Phenomenon of NMAN station

In NMAN station a clear peak is detected at frequency 20 Hz (0.05 sec) and 2 Hz (0.5 sec). We analyzed the noise peak with high probability around two frequencies by using two days data, the phenomen on observed on almost all days in 2017 (Fig. 7). We analyzed also another two different days to check the phenomenon. The PDF for Julian day350, the noise phenomenon was clear (Fig. 7a), while the PDF for Julian day 70wasn't clear (Fig. 7b). We explained this noise phenomenon at 2 Hz as a result of the high dam turbines and at 20 Hz due to the effect of the quarry blasting near the station.

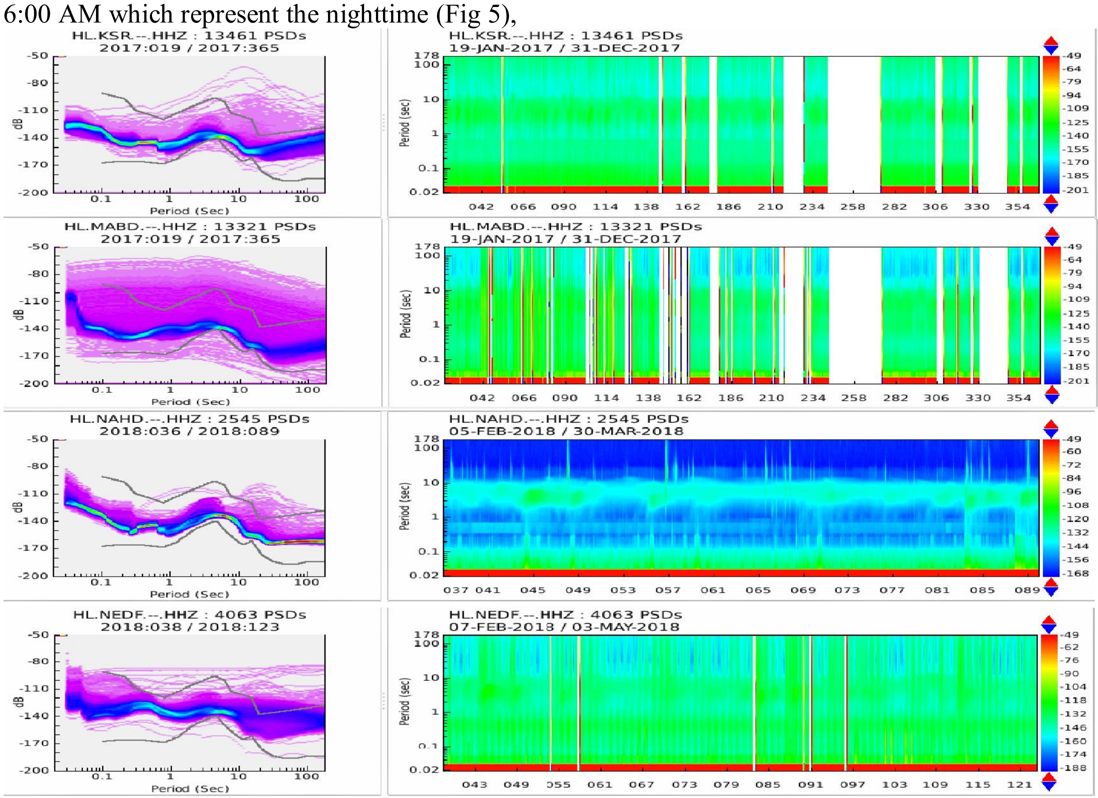

Figure 3.1: Noise PDFs of the Aswan sub-network of the Egypt broadband stations.

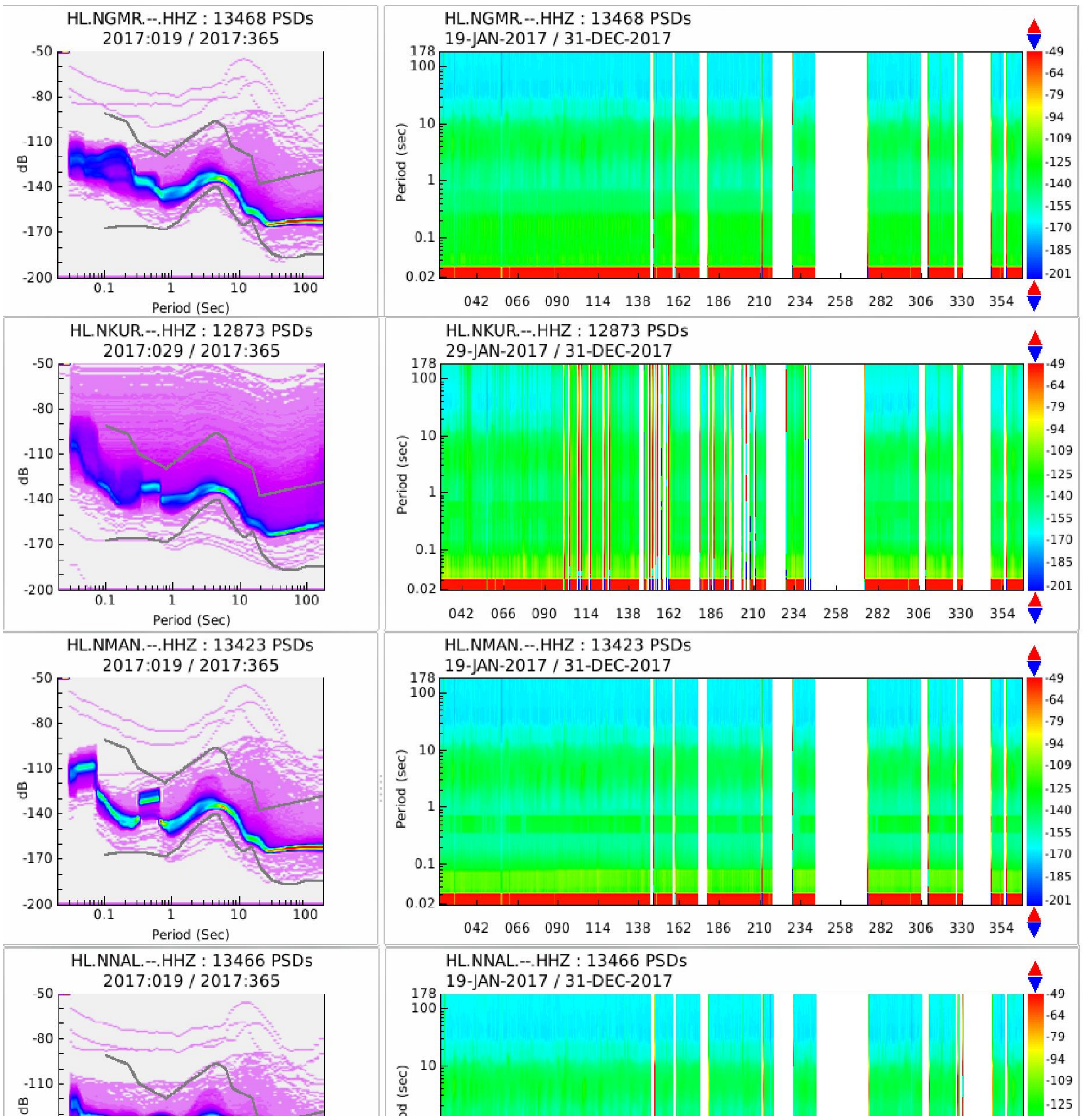

Figure 3.2: (continued) noise PDFs of the Aswan sub-network of the Egypt broadband stations.

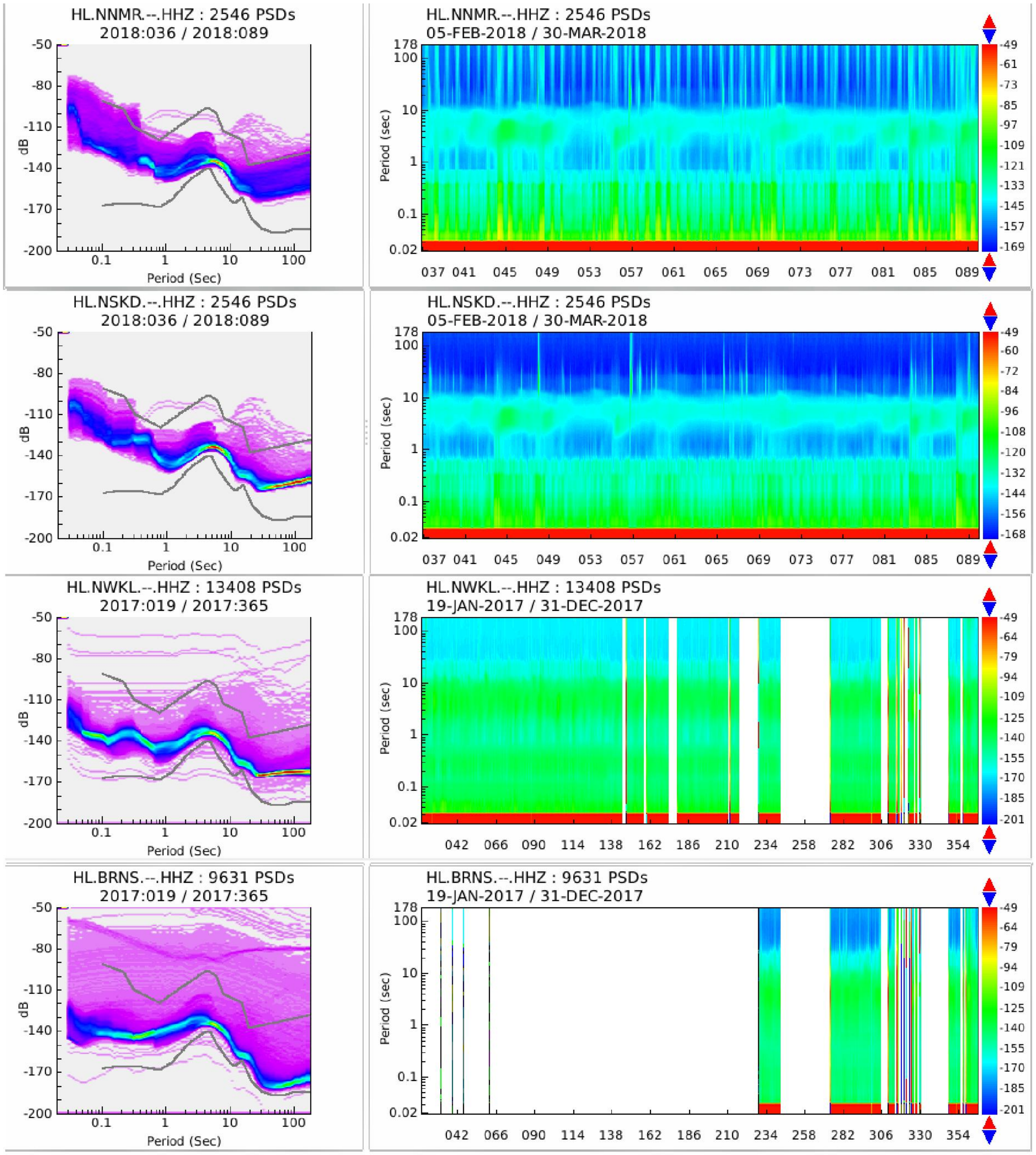

Figure 3.3: (continued) noise PDFs of the Aswan sub-network of the Egyptbroadband stations.

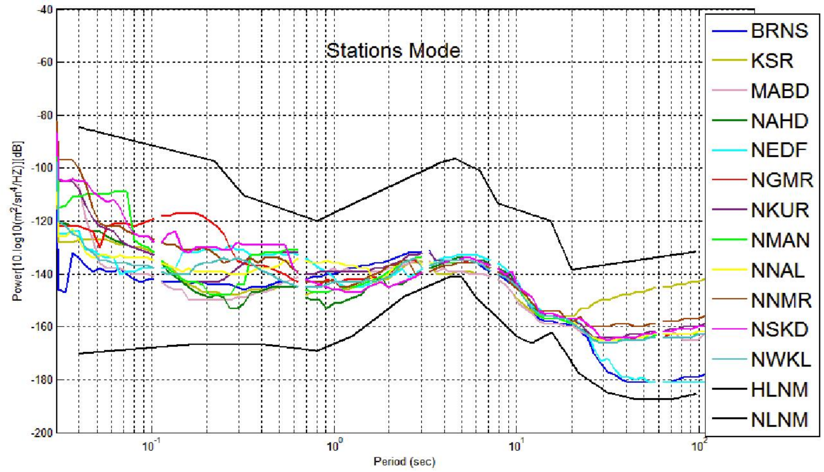

Figure.4: The noise PDFs mode the Aswan sub-network of the Egyptbroadband stations

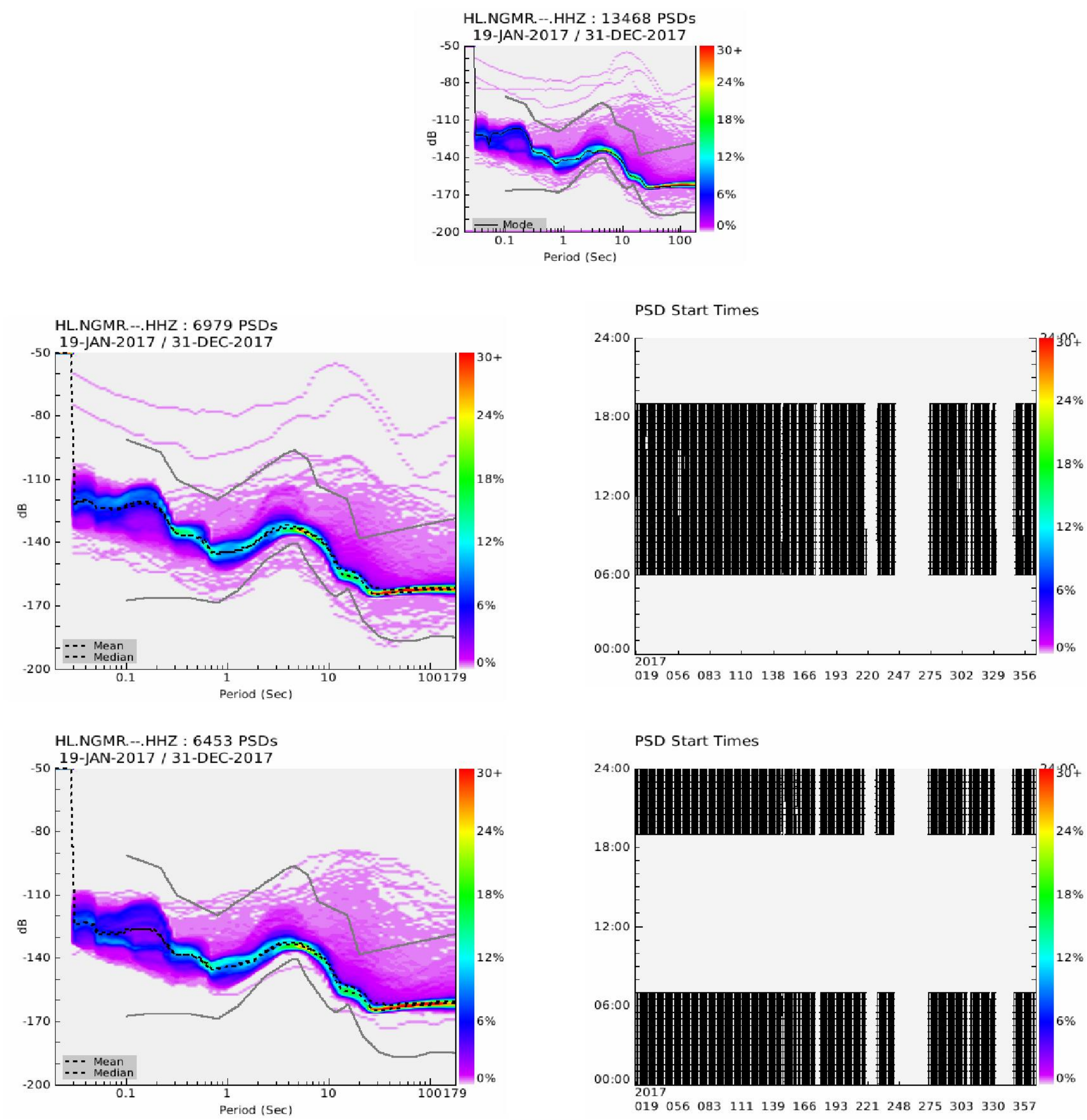

Figure.5: The PDFs of day and night of NGMR broad band station

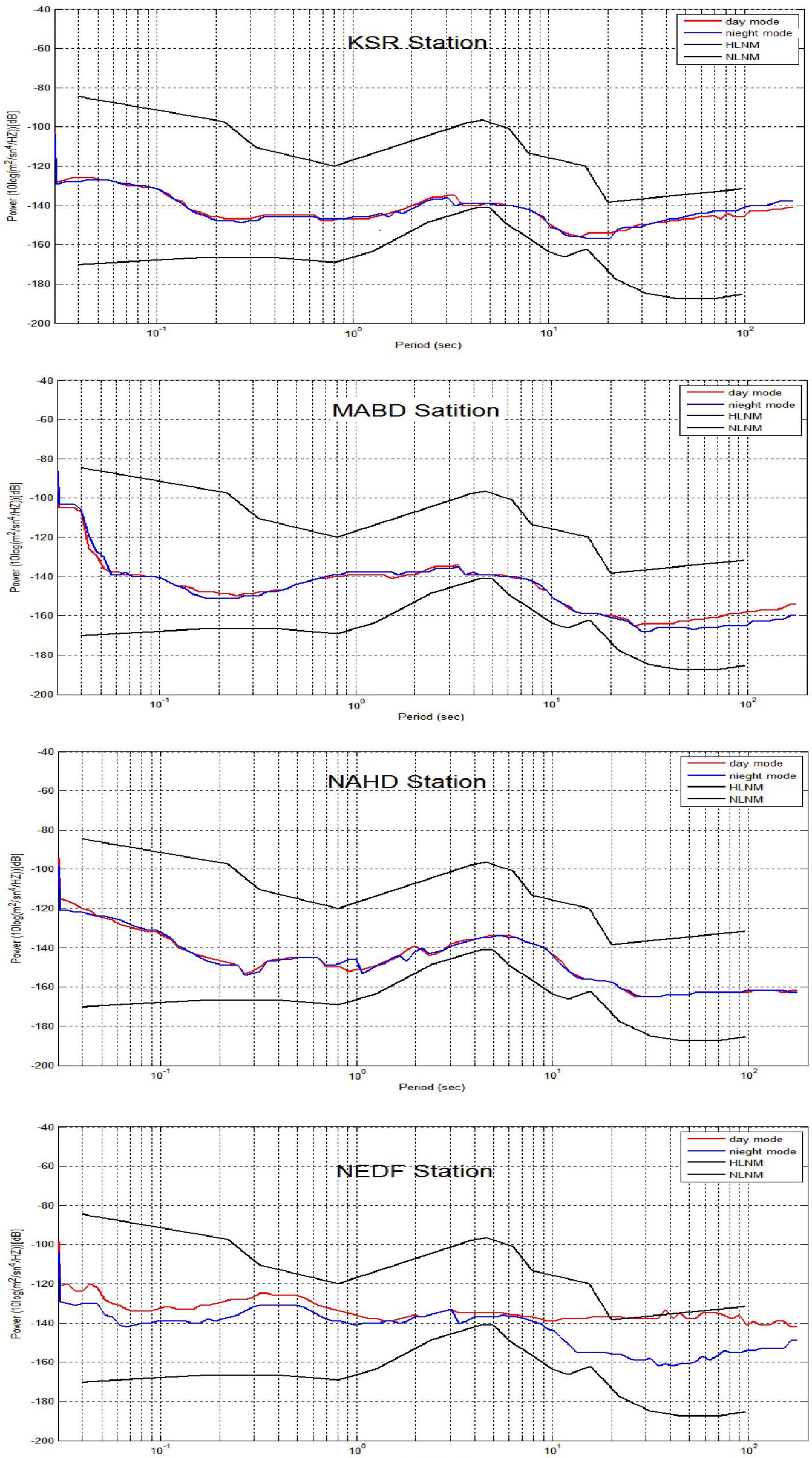

Figure.6.1: Noise PDFs Mode of the Aswan sub-network of the Egyptbroadband stations

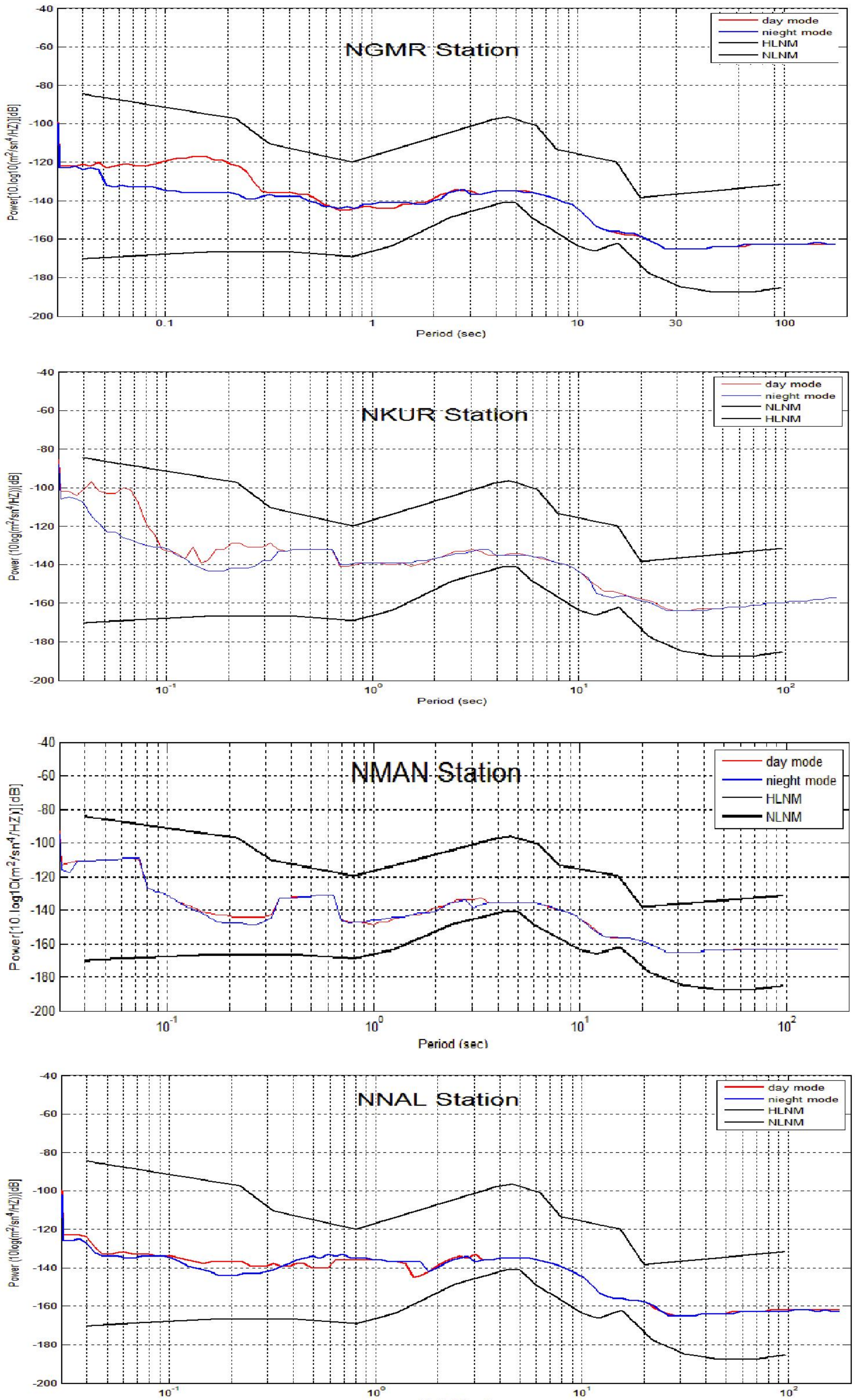

Figure.6.2: (continued) noise PDFs Mode of the Aswan sub-network of the Egyptbroadband stations

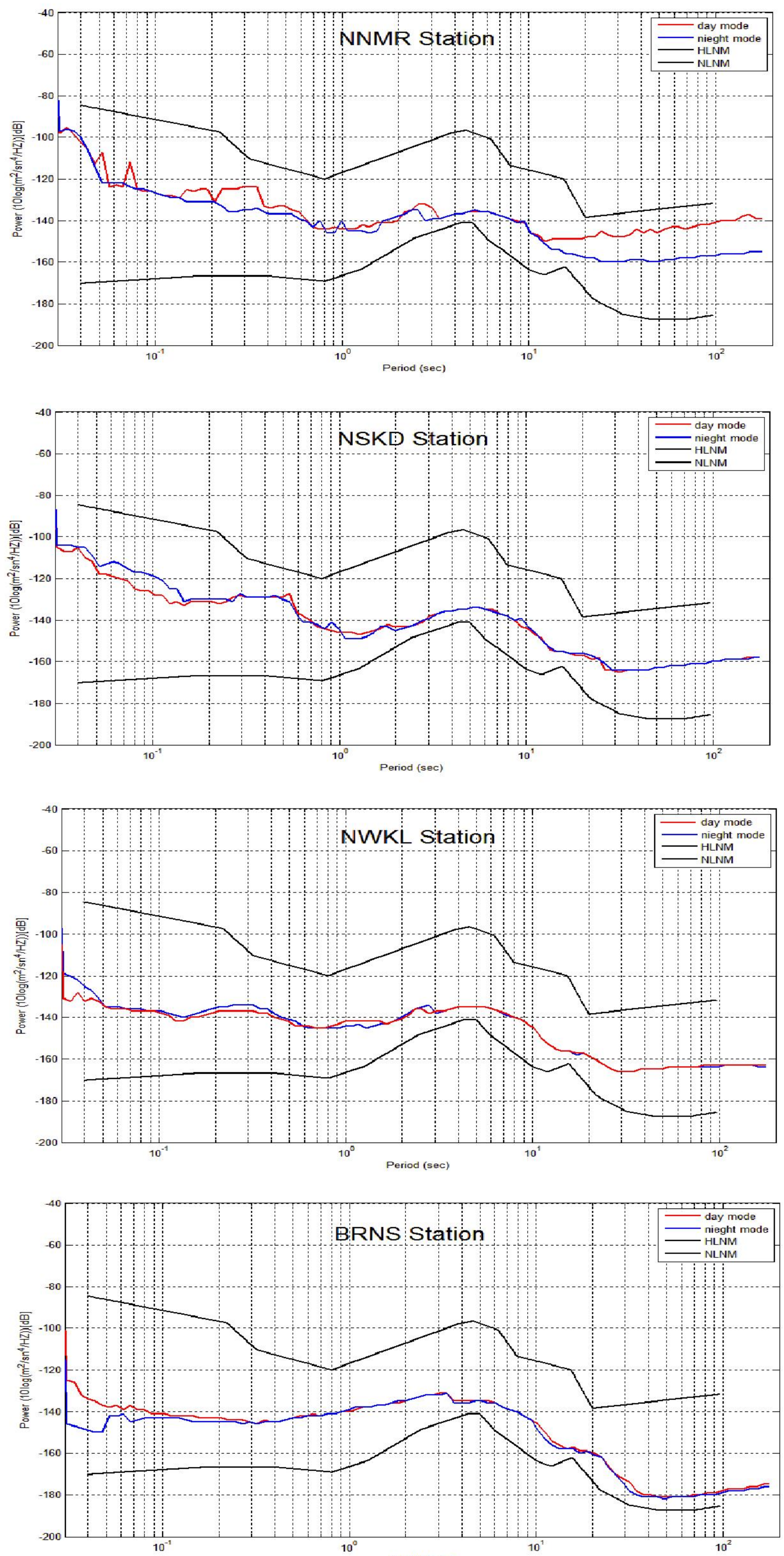

Figure.6.3: (continued) noise PDFs Mode of the Aswan sub-network of the Egypt broadband stations

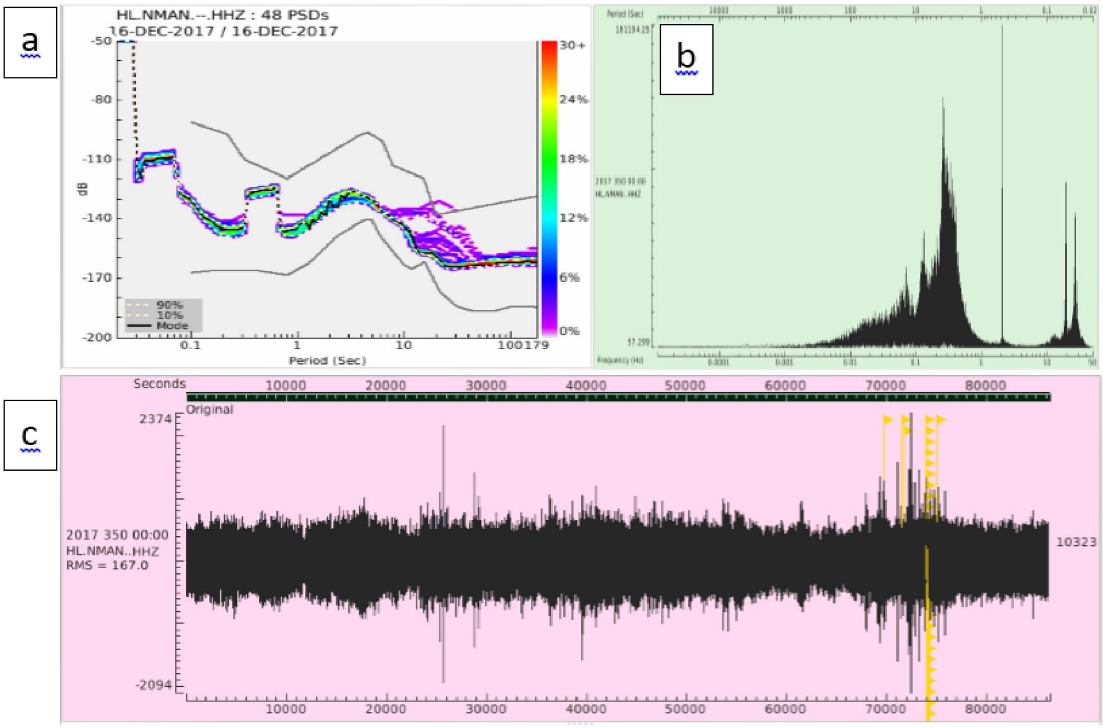

Figure.7. a: NMAN PDFs for December day 350 (a) PSD December day 350 (b) and trace waveforms (c)
Figure.7. b: NMAN PDFs for March day 70 (a) PSD March day 70 (b) March day 70 and trace waveforms (c)

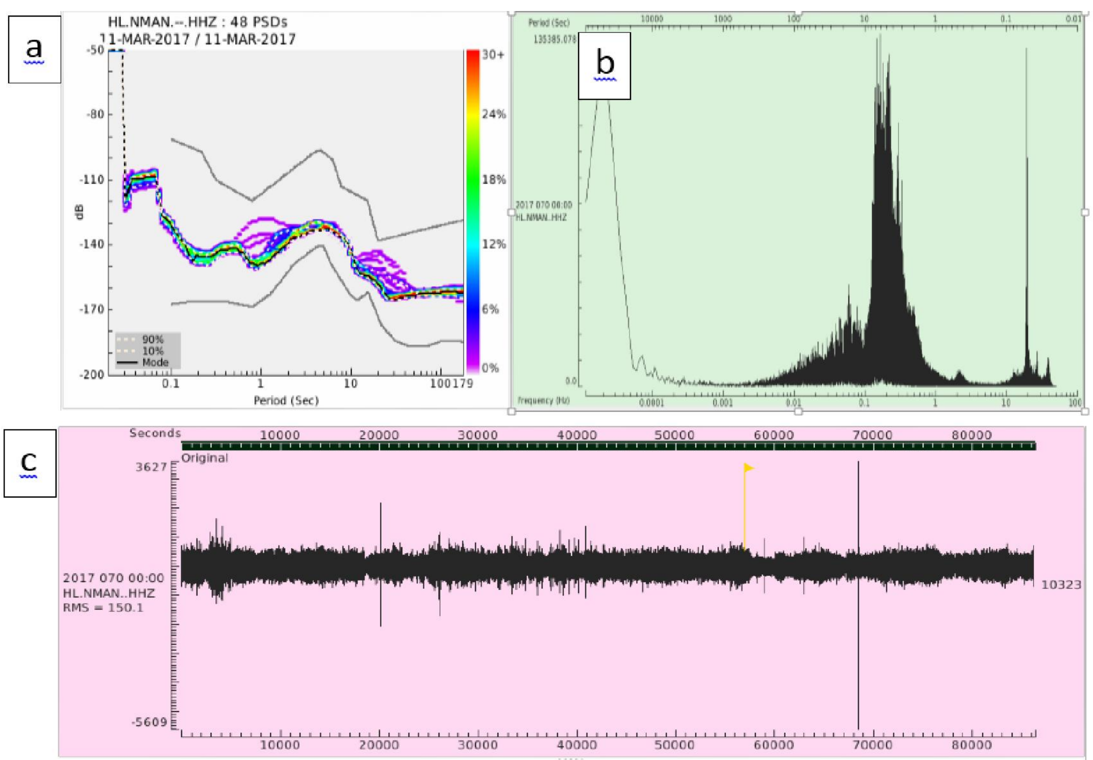

Figure 8: Noise map of bandwidth (culture noise) form 10hz -20hz (0.04s-0.1s) period band

5.4. Noise map

To show variation in the distribution of seismic noise levels for the study area including culture noise, we selected a bandwidth from10 Hzto 20 Hz (0.04s-0.1s) period band as shown in figure8. We observed that the NMAN and NSKD stations have the highest noise levels in this period range due to their permanent installation locations which are near the transportation and vehicles roads, These stations are also close to quarries. On the other hand, the NMAN and BRNS stations exhibit the lowest noise levels. Studying the Bandwidth from 0.3 Hz to 1.5 Hz (0.75s-3s) period band as demonstrated in Figure 9 show that the short body waves noise are predominant. Based on the results obtained, we have seen that the stations noise levels in this range are acceptable especially since the seismic stations are more prone to local earthquakes. The bandwidth from 0.142 Hz to 0.3Hz (3.0s-7.0s) period band as shown in figure10 shows long-period DF microseismic noise and no variation is observed. The surface wave variations are seen in the bandwidth from 0.02 Hz to 0.05 Hz (20s-50s) period band (Fig 11).

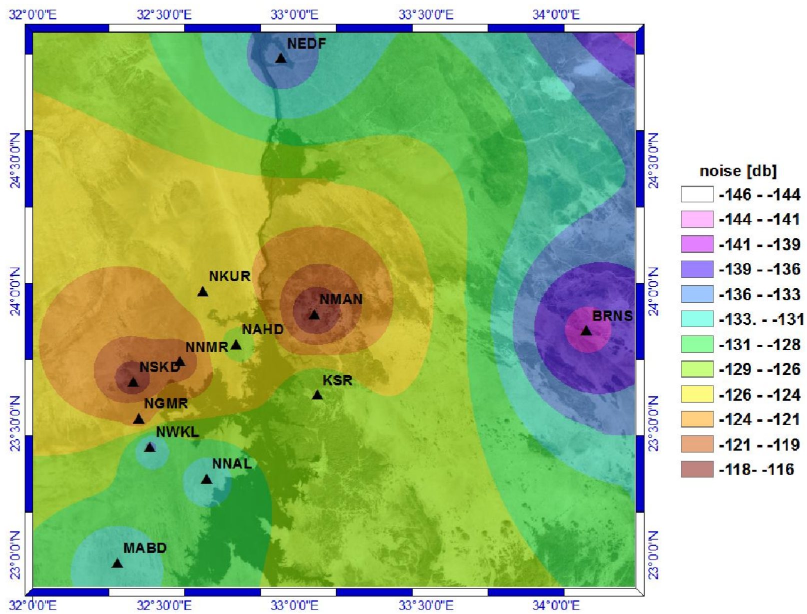

Figure 9: Noise map (show short body Waves) Bandwidth from 0.3 Hz to 1.5 Hz (0.75s-3s) period band

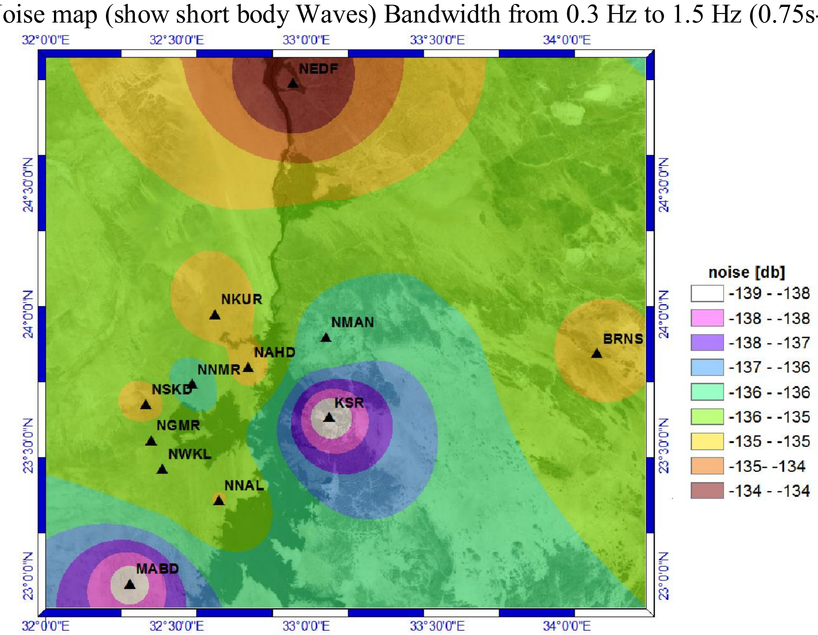

Figure 10: Noise map (show long-period DF noise) Bandwidth from 0.142 Hz to 0.3 Hz (3s-7s) period band

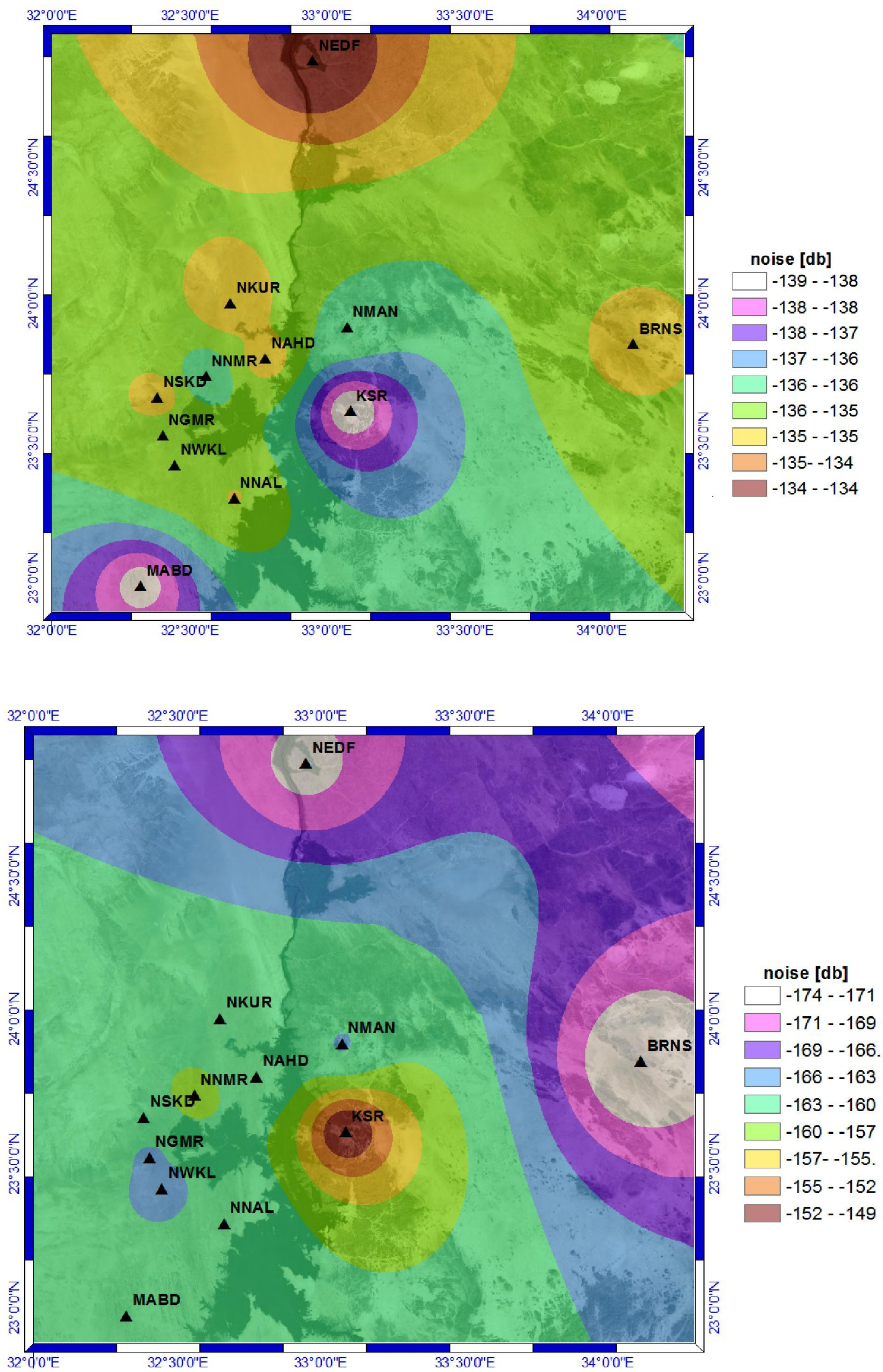

Figure 11: Noise map (show surface waves variation) Bandwidth from 0.02hz to 0.05hz (20s-50s) period band.

6. Conclusion

In this study, we used the PQLX approach to study the noise level, detectability and quality control of the seismic data recorded by the Aswan sub-network stations. It consists of 15 seismic stations, including 12 broadband seismic stations distributed around the High Dam and Lake Nasser due to the importance of this strategic area.

The result of this study includes diurnal variation which is very clear in most of the stations where some of these stations are located very close to roads (e. g. NKUR, NSKD, BRNS and NGMR stations) and this phenomenon is clear in higher frequency band. Other stations contain diurnal variation due to the bad thermal isolation and this is clear in lower frequency band (e.g NEDF, MABD and NNMR stations).

The obtained results demonstrate that the NMAN station exhibits a clear peak at frequency 20 Hz (0.05 sec) and also at 2 Hz (0.5 sec). We explained this phenomenon at frequency 2 Hz as a result of the high dam turbines while at frequency 20 Hz due to the quarry operations near the station location.

In general, we found that most of the broadband stations work in an acceptable manner and very efficiently in the frequency band of earthquakes recording, except the EDF station where this station needs to be moved to another place with good isolation.

There are many types of noise sources in Aswan area which clearly appear in most of the stations. All seismic pulsations either resulting from natural sources such as Earthquakes or artificial turbulences can be distinguished using the probability distribution function (PDF) predictable from the power spectral densities (PSD) of the ambient noise at any place. The performance of the raw seismic data at twelve broadband stations of Aswan sub network of the ENSN network in the northern part of Egypt are studied as a first step toward studying the ENSN network performance and detectability in the whole Egyptian territory using the Power Spectral Densities (PSD) analysis.

The results of this noise analysis are useful for characterizing the performance of deployed different broadband ENSN stations, for determining the operational obstacles, and re-installation of some noisy station location to reduce their background noises. Based on our results, we recommend that the NEDFv station may need more isolation or moving it to another site, due to the culture noise which is higher than normal mode in this station. The results show that the moderate in some stations near the high dam with phenomena around 0.5 sec could be interpreted as heavy machinery (high dam turbines).

Accordingly, based on the obtained results of this study we recommend re-distribution of sub-network stations by increasing the number of stations in the eastern side of Lake Nasser. We also recommend that, the noise surveys should be conducted prior to the final selection of sites for installation of seismic stations. Finally, we conclude that studying the detectability of aseismic incident are more valuable than noticing a signal higher than level of the noise at one station.

7-Acknowledgments:

We thank the Egyptian National Seismic Network (ENSN) for providing the raw seismic data. This work was supported financially by the Science and Technology Development Fund (STDF), Egypt, (Grant No, 25553).

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3/17/2020