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Studying microseismicity in the central part of Sri Lanka using Waveform Cross-Correlation

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1. ABSTRACT

A plethora of micro-seismic activities has occurred in Sri Lanka in the past few years. Considering them, most of the seismic activities occurred in the central region around Haragama Digana, Kandy, and Walapane. A sequence of micro-earthquakes (M_w<3) was felt by the dwellers in the region between 1st February 2020 to 30th January 2021. Waveform cross-correlation technique assists to govern anonymous microearthquakes. Waveform cross-correlation (WCC) can be considered a powerful seismological tool used to detect the precise similarity of waveforms. Python (ObsPy package) was the main computational tool to detect unspecified multiplets(groups of similar events). P and P coda wave of the main event which was recorded on the Pallekele (PALK) station was considered with an appropriate time window respectively to identify the new event. Out of 10 events considered, we could detect 5 new events with a high cross-correlation coefficient (CC> 0.50). Thereafter, the other seismic stations in Hakkamana (HALK) and Mahakandarawa(MALK) were used to verify the tremor. This unspecified seismic swarm helps to identify the central region's seismogenic zone.

Keywords: micro-seismic, microearthquake, cross-correlation, seismogenic, swarm, P coda

2. INTRODUCTION

The origination, propagation, and evidence of seismic waves and their sources are studied through seismology. Studying elastic waves opens the investigation of a high resolution of the earth's interior, which provides a greater understanding than other geophysical methods [1]. Earthquakes occur due to the energy released in the tectonic plates. As a result of the energy of the earthquake, waves travel through Earth's layers, these types of waves are called seismic waves. Seismologists classify earthquakes into different categories according to the Richet magnitude Scale. More specifically earthquakes that record a magnitude less than 3 are referred to as micro-earthquakes or earth tremors [1]. Sri Lanka has been recognized as an aseismic or Stable Continental Region (SCR) because of its location on the Indo-Australian Tectonic plate [2]. But small earthquakes have been recorded in many parts of Sri Lanka. Mostly found in Digana, Pallekele, Kundasale, and Kandy regions [3]. Sri Lanka has three global seismometers which are located in Pallekelle (7.273ºN,80. 702ºE), Mahakandarawa (8.9682ºN,80.54254ºE), and Hakkmana (6.0877ºN, 80.6806ºE) region [4]. The aim of this project is to identify anonymous micro-earthquakes, which occurred in the central region of Sri Lanka. To identify the anonymous tremors, the statistical concept called waveform Cross-Correlation was used. Waveform Cross-correlation computes the similarities between two series of the function of displacement of one relative to the other as a function of time shift or time lag [5]. The cross-correlation method is a highly sensitive method, even in low background fluctuations, because the changes will not affect the component peaks and will be get attenuated. Identifying microearthquakes helps to identify the structural behaviour of the area, it provides an early sign

of large earthquakes, and seismic risk statics can be identified and minimize major damages to hydropower plants and dams [1].

3. METHODOLOGY

The area considered for the studies is a latitude range of 5.8° -10.0° and a longitude range of 79.5° -82.0°. The micro-seismic activities that occurred from 2020 to 2021 in the central region were considered for the study. Python ObsPy package was the software used to access and scan data through the web servers of the seismic stations. Firstly, information on seismic events was gathered from newspaper articles and other related documents. Next, seismic data related to the PALK station was loaded from the IRIS web server with the relevant properties [6]. (Date, Time, band pass Filter, component, channel, etc..).Here the time domain of continuous seismic waveform was used to identify the correlation coefficient [7]. Then, P and P coda (for small events P and S wave is considered) wave was identified from the main tremor. To identify the P and P coda wave, the envelope function was used (figure 1). Here the time between P and P coda was considered as the time window for the Cross-correlation (figure 2). Using the time window, cross-correlation coefficients were found. Thus, the source code was run for 12 hours before and after the event to recognize higher coefficients (CC >0.5) for the continuous seismic waveform. For higher coefficients in the PALK station, the time was noticed down, and the correlation was done for the other station MALK and HALK as well as for all the components [8]. If all the stations have considerably higher values this waveform is considered a tremor.

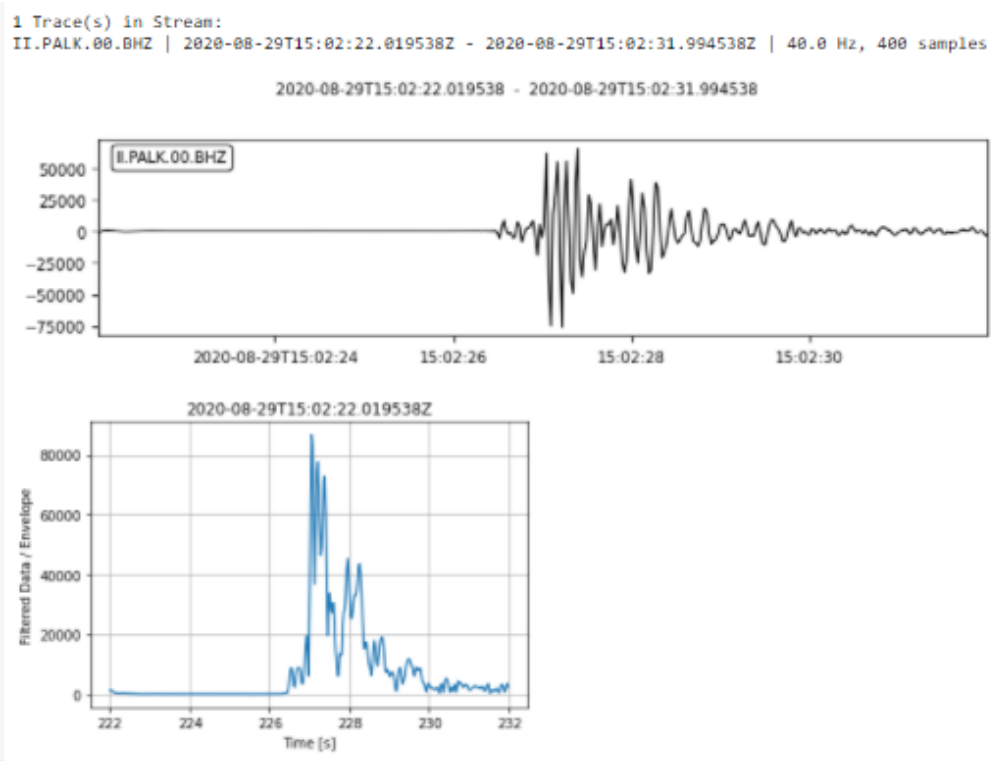


Figure 1: Waveform of a main tremor and its envelop waveform

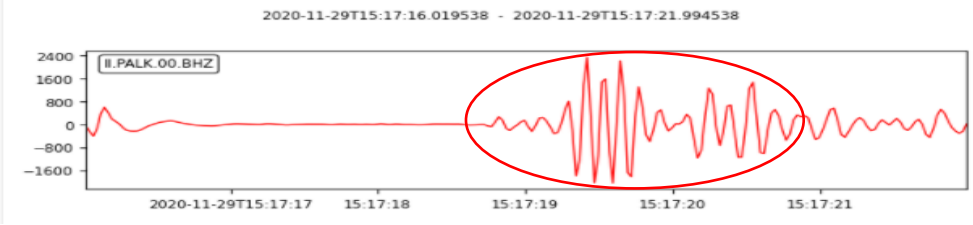
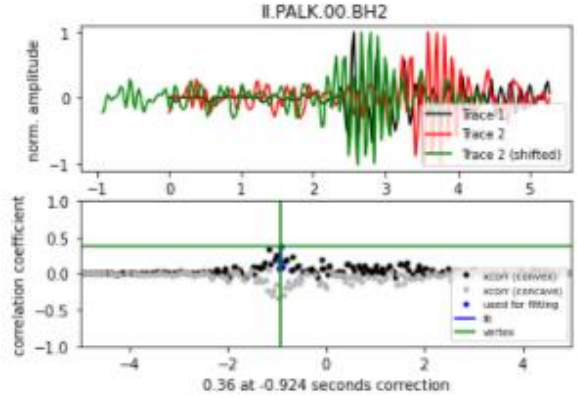


Figure 2: Identify the P and P code wave from the continuous seismic wave. Here, both P and S wave were selected because the event was small therefore this could be the time window.

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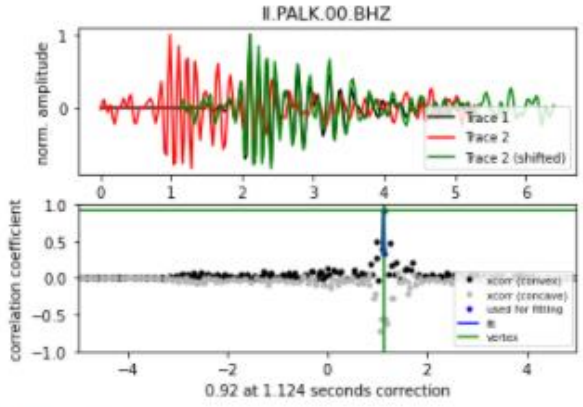
No preprocessing:
  Time correction for pick 2: 0.924190
  Correlation coefficient: 0.36
```

Figure 3: Waveform cross-correlation coefficient and the correlation time for the main event and the found the anonymous event. Here coefficient found was 0.36 which is much closer to the main event. The second graph depicts individual coefficients obtained for each amplitude while black represent the convex and grey dot represents the concave nature of the coefficients of the amplitudes.

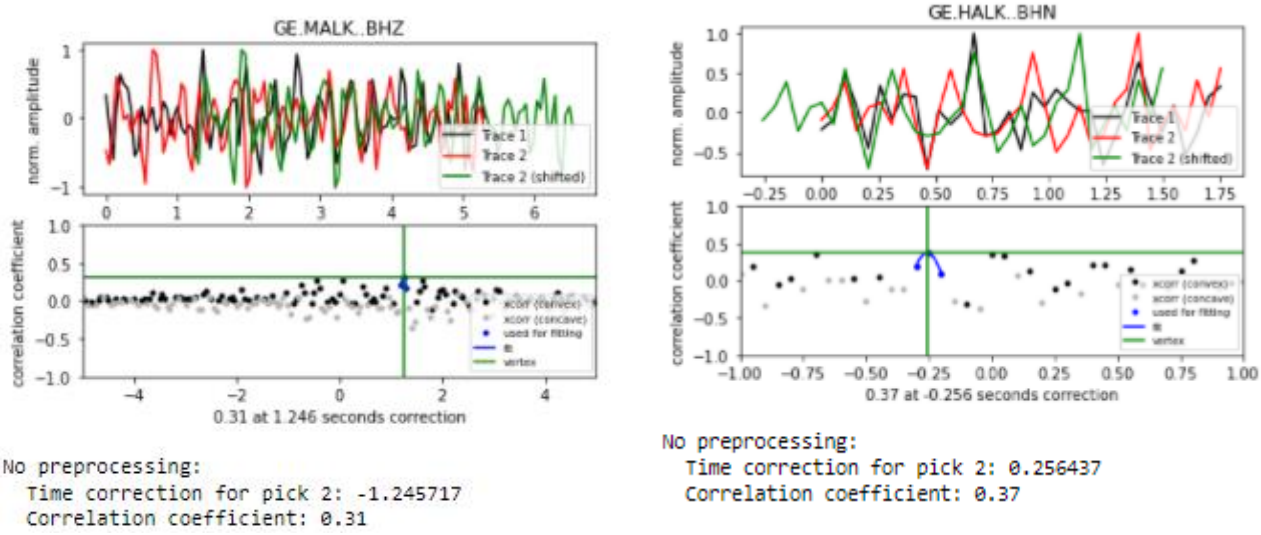
4. RESULTS

Waveform Cross-Correlation was performed for the main events and higher coefficients were WCC with other stations and channels before the event is verified. Figures 4 and 5 below show some of the WCC performed and anonymous events found.




```
No preprocessing:
  Time correction for pick 2: -1.124410
  Correlation coefficient: 0.92
```

Figure 4: WCC coefficient found for the main event and its time lag for PALK BHZ channel (anonymous event)

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No preprocessing:
  Time correction for pick 2: -1.245717
  Correlation coefficient: 0.31
```

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No preprocessing:
  Time correction for pick 2: 0.256437
  Correlation coefficient: 0.37
```

Figure 5: WCC coefficient found for the main event and its time lag for MALK BHZ channel and HALK BHN channel

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1 Trace(s) in Stream:
II.PALK.00.BHZ | 2020-11-18T04:00:11.019538Z - 2020-11-18T04:00:24.994538Z | 40.0 Hz, 560 samples
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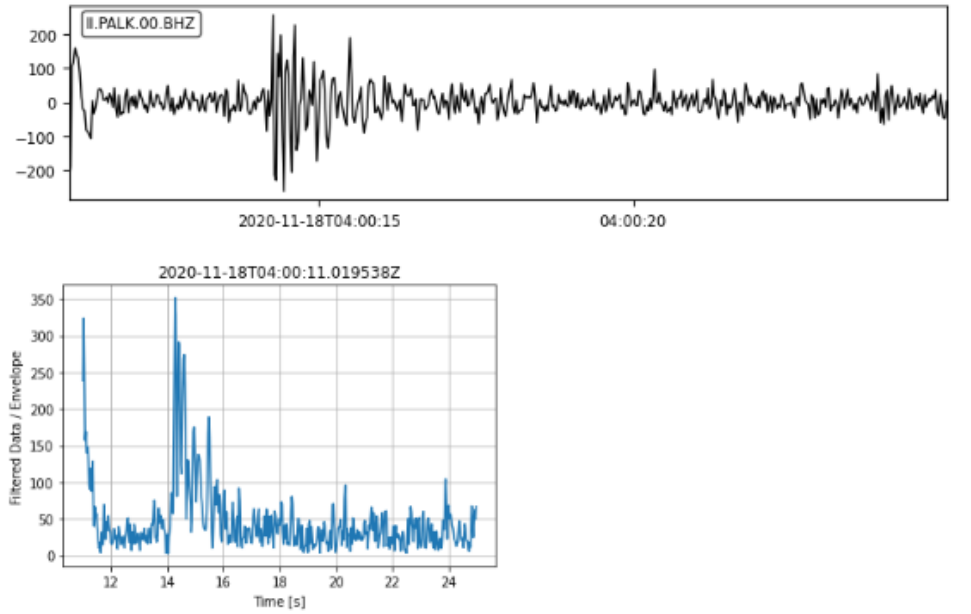

Figure 6: Waveform of anonymous events found which has a higher coefficient of 0.92 and its envelope function PALK BHZ

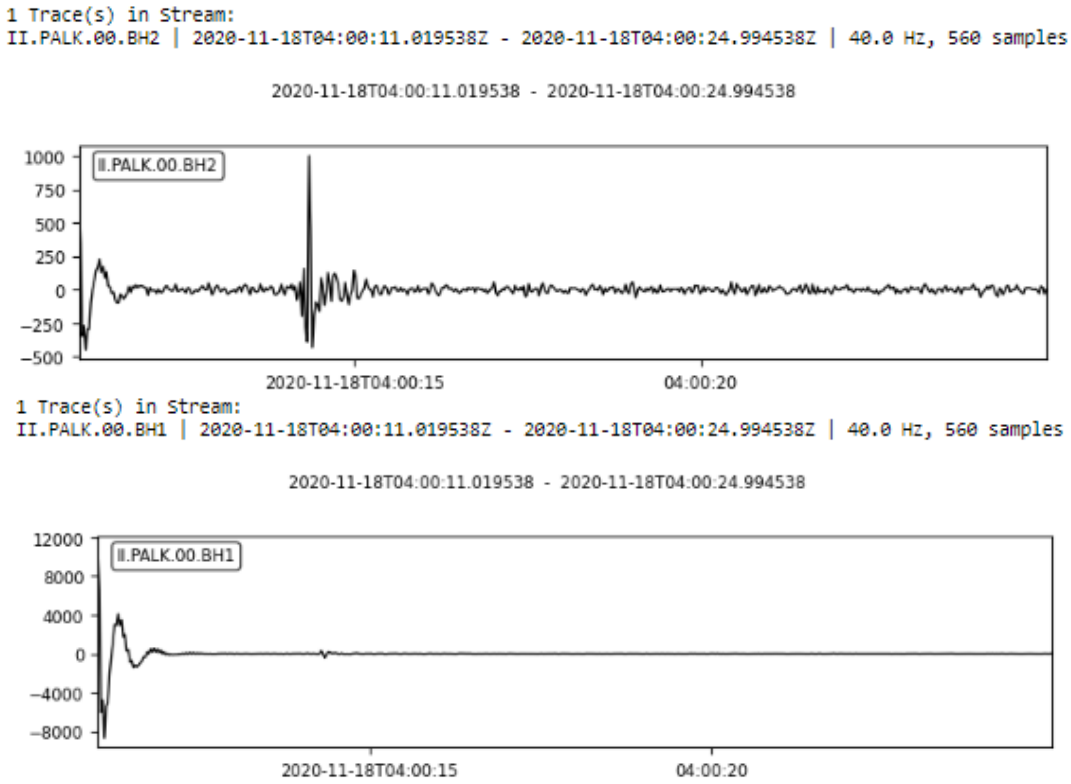

Figure7: Waveform of the anonymous event found PALK BH1, BH2 components

5. DISCUSSION

For this study, micro-seismic activities were considered from January 2020 to June 2021. From June 2021 no significant micro-Earthquakes occurred in the central region [3]. For the statistical analysis, 10 events were considered as said by the civilians in the central region. Tremors are considered to be independent of each other. Waveforms were obtained with background noise. Here the waveform was passed-through band-pass filter in the range 2-9 Hz. MALK and HALK stations have a sample rate of a Maximum of 20Hz while PALK station has a sample rate of 40Hz, therefore, filtering information might be a loss, so to avoid it Nyquist Theorem was used. For separate events, the time windows are different. Throughout this study, only the P and P coda waves were considered for correlation. For small events, P and S waves are selected to Correlate. This is because P and S waves are located only a few seconds apart. Using only the P wave the error could be higher. WCC is done for each second throughout 24 hours. Approximately 865,000 coefficients were performed to find out the Higher coefficients. After obtaining CCC to verify the events CC was done for the other stations and channels. Considered time window with a slight time lag was considered to correlate with other stations. Here other than the PALK station, all the other station record lower coefficients comparatively. This could be because the study considered microseismic activities and intensity decrease with the distance stations are far apart. Thus, vertical components depict the highest coefficients compared to other stations.

6. CONCLUSION

Throughout this study, 10 main events were considered, however out of them 5 new tremors were found which has a coefficient(CC>0.50) and higher. The study was limited to a period from January 2021 – June 2022. Thus, could depict that there could be additional anonymous microseismic events in the past events and seismic events yet to come. The increase of microseismic events in the central region may be due to the activation of old faults or due to the effects of large reservoirs. This technique can be considered to analyze Reservoir Induced Seismicity (RIS) within the region and also to identify seismic swarms within the region [9]. Thus, these reservoirs cause a large amount of stress on the rock underneath due to the weight of the water column. These could be seismic swarms or aftershocks of the main events. Since these events have very low magnitudes these events may not be felt by the dwellers within the region. This project could be extended by locating the found anonymous events graphically on the map either using the triangular method or particle motion analysis.

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