Characteristics and origin of microseisms around Taipei city

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Introduction

In seismology, ambient noise in cities is driven by numerous man-made processes including traffic, subways, airports, and industrial activities. A good understanding of the spatial and temporal variations of the city noise is crucial, for the successful utilization of seismic noise especially in urban environments.

The Taipei city is known for the political, economic, and cultural center of Taiwan with population of 2.4 million people. This metropolitan area is located in a Quaternary sediment-filled basin with low seismicity. A very dense seismic array named Formosa Array (call it FA for short) was deployed since 2018, to investigate the geometry of the magma chamber beneath the Tatun volcanic area. With ~5 km spacing and 140 seismic stations, FA also provides an excellent opportunity to study the characteristics and origin of seismic noise in cities driven by numerous processes. FA is conducted by the Institute of Earth Sciences of the Academia Sinica and the Tatun Volcano Observation at Tatun.

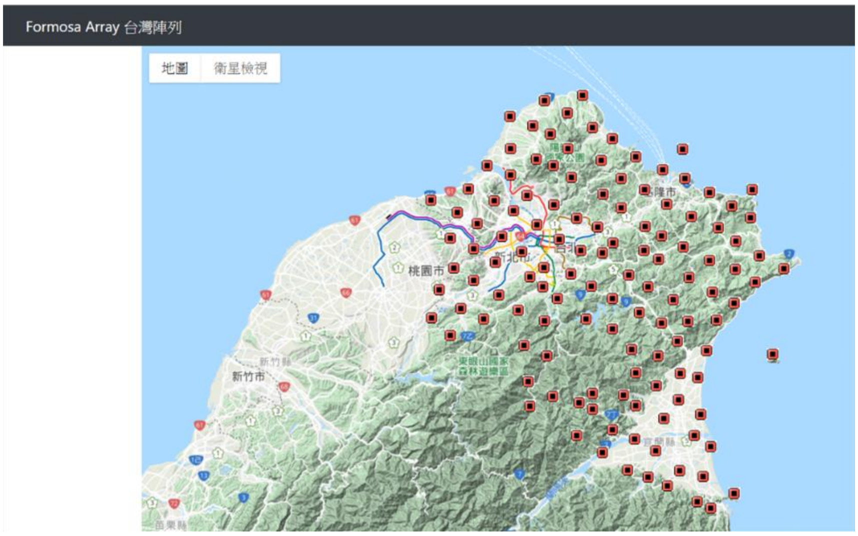


Fig1. Location of FA stations in google map

By examining continuous seismic data recorded in high dense broad-band seismic network (FA), we aim at exploring:
(1) how many types of recurring, strong Noise are produced by human activities in Taipei city
(2) what are their characteristics and origin.

We first analyzed the vertical component of continuous seismograms with 100 Hz sampling rate starting from Jan. 1st to Feb. 27th, 2019. We removed mean, trend, and instrument response to further obtain the median and maximum value of the amplitude in each day. Previous study indicates that the station located near metro station reveals significant amplitude distinction between daytime and nighttime occurs mainly in a range of 2-20 Hz. The stations analyzed in this study are colored, including KE, KM, LK, PN, VO, and WU stations. Here the CT stations were previously investigated by Yeh et al. (2020).

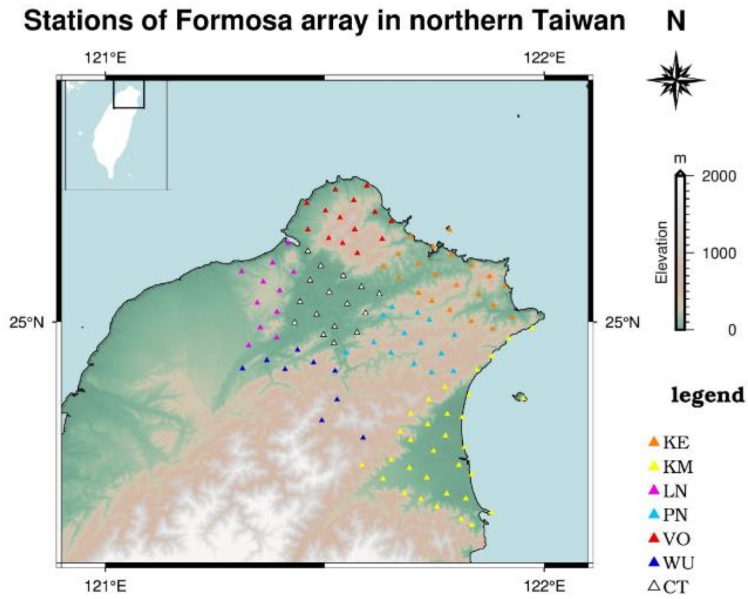


Fig2. Location of FA stations in self-made map. Coloring by groups.

To study the frequency-time characteristics, we calculated the long-term spectrograms for time series. In processing the frequency-time analysis, the frequency and corresponding amplitude is computed every 1-hr with 0.5-hr overlap. The station located near metro station reveals significant amplitude distinction between daytime and nighttime occurs mainly in a range of 2-20 Hz, indicating strong association with traffic. There exists secondary energy of 0.2-1 Hz and < 0.2 Hz in the spectrogram.

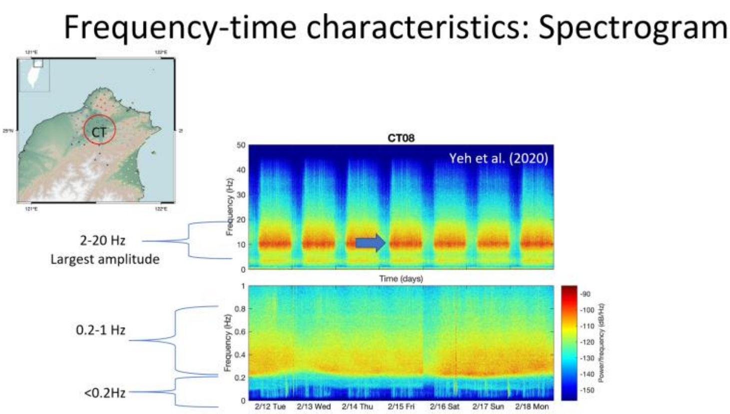


Fig3-1. Raw data, spectrogram in two frequency bands (0-50Hz, 0-1HZ)in CT. Showing the three distinct frequency bands we are selected for analysis.

It is different from the 2-20 Hz concentration in city stations, the station located in KE area however, reveals largest amplitude at 0.25-1 Hz. The same dominance is found at stations outside the city.

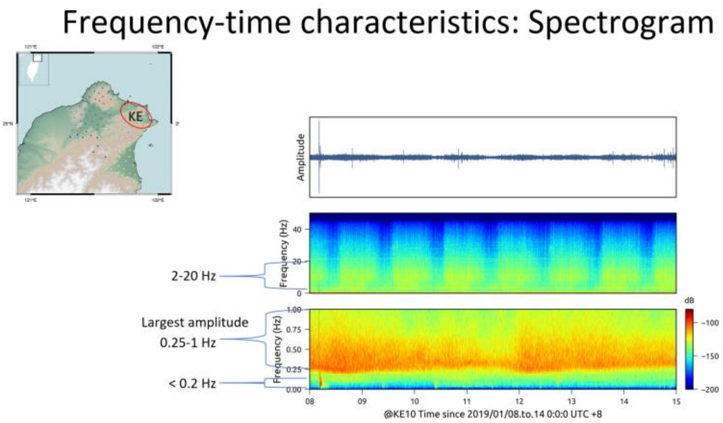


Fig3-2. Raw data, spectrogram in two frequency bands (0-50Hz, 0-1HZ) in KE. Showing the three distinct frequency bands we are selected for analysis.

Method & results& discussion

1. Characteristics of low-frequency noise

So the three distinct frequency bands are selected for the following analysis. In order to study the spatial and temporal variation, we computed the daily maximum, median amplitude at each stations.

Based on spectrogram, three distinct frequency bands are selected: <0.2 Hz , 0.25-1 Hz , 2-20 Hz, Spatiotemporal variation of amplitude over two months for each subarea

(1) daily maximum amplitude

(2) daily median amplitude

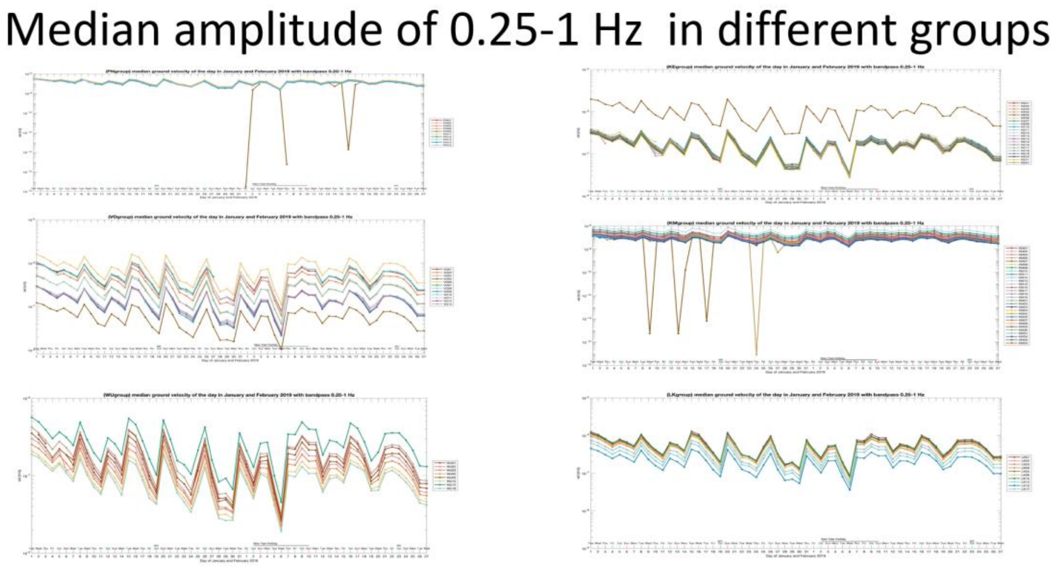


Fig4. Daily median of six groups in 0.25-1Hz.

Here’s the daily median of six subarea in two bands (we only showed one for example), you can see the trend of these six areas is similar, that means it has a high probability that have same source origins.

2. The origin of <1 Hz noise?

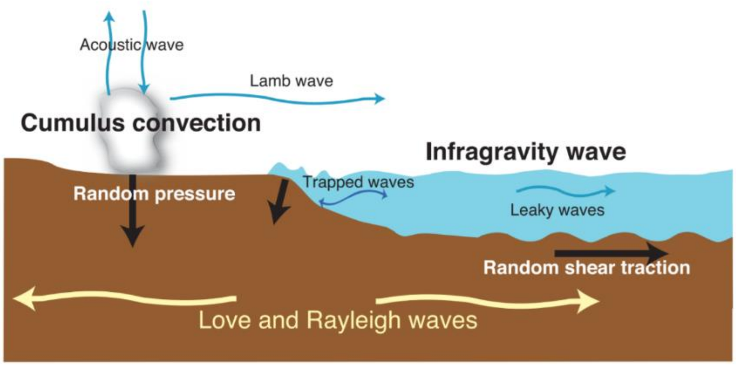


Fig5. Schematic figure of possible excitation mechanisms of seismic hum. Source from *Source spectra of seismic hum* (Kiwamu Nishida, 2014)

The ambient noise around 0.01-0.1 Hz and 0.1-1 Hz is recognized as the primary and secondary microseisms, which is a persistent seismic wave field excited by ocean swell activity. The physical model below says that the atmospheric and oceanic disturbances are able to produce long-period vibration.

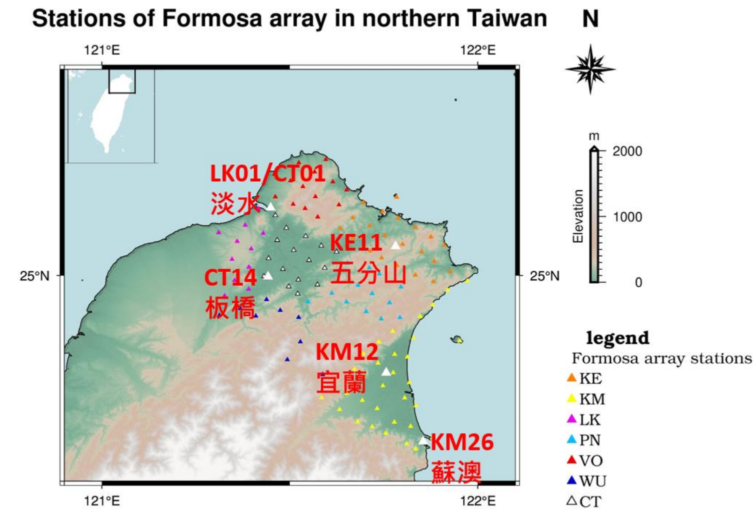
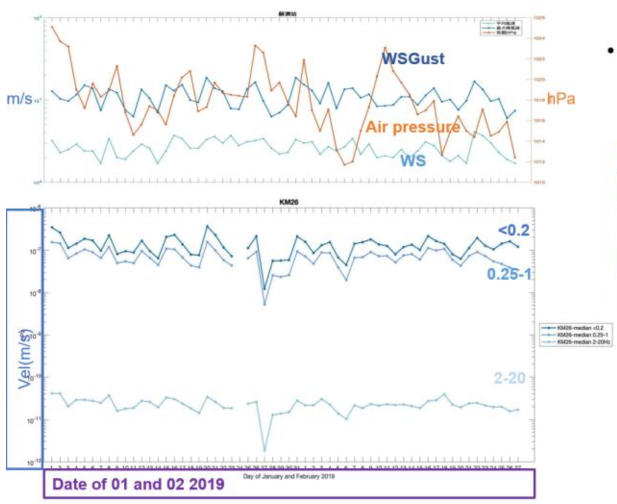


Fig6. Location of FA stations in self-made map. Coloring by groups. White triangles are weather stations. Stations name and surrounding FA stations number are appended

We want to know how's the correlation between weather and microseisms. We picked 5 weather stations, and because we believe that the area affected by weather phenomena is not large, we picked 6 seismic stations next to the weather st. and calculate cross correlation coefficient about every variable of weather.

Su-ao v.s. KM26



- The cross-correlation coefficient (CCC) between seismic noise is largest with wind gust, higher than 0.4.

CCC			
Frequency band	WS	stnpress	WSGust
< 0.2 Hz	0.34	0.24	0.62
0.25-1 Hz	0.28	0.23	0.59
2-20 Hz	0.15	0.15	0.45

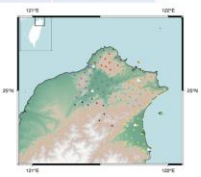


Fig7.

We chose avg. air pressure, avg. wind speed, maximum wind gust as variables. Because the maximum and minimum air pressure trends are close to the average air pressure trend, and the air pressure difference is not related.

Fig7 is the comparing between daily median of 3 bands of seismic amplitude and weather station data. The table is C.C.C. between variables
The C.C.C. means cross correlation coefficient, and WS means wind speed, stnpress is avg. air pressure, WSGust is daily wind gust.Here, the correlation between seismic noise is largest with wind gust in Su-ao v.s. KM26.

From the figures (we only showed one for example), we can see that the C.C.C. of wind speed is larger than that of air pressure, the difference of C.C.C. between the maximum gust and the average wind speed is not much.

The comparison with different weather stations suggest a common feature:
(1) The average wind speed & wind gust have higher C.C.C.
(2) The 2-20 Hz generally has lowest C.C.C.

Conclusion

During the study period from Jan. 1st to Feb. 27th, 2019, we analyzed the 108 stations located in Taipei metropolitan area. The time-frequency properties of seismic data show three types of recurring, strong noise that are associated with human and/or natural activities. They are characterized by distinct frequency bands of (1) 2-20 Hz (2) 0.25-1 Hz (3) <0.2 Hz. The amplitude of 0.25-1 Hz remains largest at stations outside the city, while inside the city (around the metro system), the seismic noise level is dominant by 2-20 Hz energy. At frequencies higher than 2 Hz (mainly 2-20 Hz), seismic noise systematically exhibits daily and weekly variation, indicating an association with human activity. At frequencies lower than 1 Hz, the temporal variation in daily median amplitude reveals high similarity over a wide range of area (including 6 groups of stations). Such trend shows higher correlation with wind velocity (either average or maximum value) instead of air pressure. This suggests that the atmospheric perturbance may play an important role on <1 Hz noise level.

Acknowledgements

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