Dense Microtremor Survey for Site Effect Study in Taiwan

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ABSTRACT:
The site effects were analyzed from dense microtremor survey in Taiwan, including 3917 survey points in this study. The measurement interval was two to three kilometers in most of the region, and it is five hundred meters to one kilometer in the city. Data processing is from H/V spectral ratio method, which could analysis site responds of the station without reference rock site. After data processing, the dominant frequency was analyzed in every single station, and displayed with contours. It represented the information of deposit thickness and S-wave velocity of the main alluvium layer, and the P-S logging results can be compared. The amplification factors at different frequencies can be shown; it reflects the site response at that frequency. Finally, all the results are combined with the GIS system, and hope these results can be used in many purposes like earthquake engineering, disaster prevention, seismological study, and land use planning.

Keywords: microtremor survey, H/V spectral ratio, dominant frequency.

1. INTRODUCTION

Taiwan is located on the seismic zone of rounding Pacific Ocean area. There are lots of earthquakes occurred every years, so we need to consider about earthquake ground motion. The inference of the earthquake ground motion can divided into source, path, and site effects. Moreover, the site effect usually plays the most important role in earthquake disaster, so many people using reference site spectral ratio method to study the site effect (Borcherdt, 1970; Chávez-Gracía et al., 1990; Field et al., 1992). After calculating the spectral ratio, site amplification factor will be identifiable. But it's hard to find the reference rock site after all. Nakamura (1989) investigated that the site amplification factor can be identified from microtremor which been recorded by a single station, the method is so-called H/V spectral ratio method. This method improves the site effect researches very much. Economize on its cost, time and manpower, the greatest advantage is no need to wait earthquake occurred. So the site characteristics of Taiwan region were analyzed by dense microtremor survey in this study.

2. MEASUREMENTS AND DATA PROCESSING

2.1. Microtremor Measurements

The microtremor survey had been constructed during 2001 to 2006, including 3917 survey points spread in plain, basin, and hill region of Taiwan (Fig. 1). Each point measured microtremor for 18 minutes, and the sampling rate is 200 points per second. Three-component acceleration and velocity had been recorded. The position of each point was carefully selected to avoid artificial noise. The seismometer we used is made from Tokyo Sokushin, including the recorder SAMTAC-801B with 24 bits resolutions and the sensor VSE-311C with the frequency response from 0.07 to 100 Hz.

2.2. H/V Ratios Analysis

After the data been recorded in every survey points, they were cut into many time windows of 40.96 seconds long. The windows with notable noise were eliminated. Three-component spectra of these windows were calculated with Fast Fourier Transform (FFT). Following H/V spectral ratio method's step, the horizontal spectra were composed by NS and EW component, and divided by vertical spectra to get H/V ratios for each window. After all, the mean H/V spectral ratio was calculated for all windows, and plotted with plus and minus one standard deviation (Fig. 2). The H/V ratios for all survey points were used to find out the variation of site characteristics in the studying region.

H/V spectral ratio can show the site characteristics. The dominant frequency of each station was marked and the contours for Taiwan region can be plotted (Fig. 3). The dominant frequency reflects the main site characteristic of underground structures at the survey points.

In order to verify the dominant frequency, the shear-wave velocity data from borehole measurements were used. Based on the 1D resonant relationship:

$$F = V_s / 4h \tag{2.1}$$

where F is resonant frequency in Hz, V_s is shear-wave velocity in m/s, and h is thickness of the deposit in m. Fig. 4(a) shows the shear-wave velocity measured from borehole survey near the strong motion station ILA033. And the H/V spectral ratio from nearest microtremor station was also plotted in Fig. 4(b).

The site amplification factors of different frequency bands were plotted in Fig. 5. The contour for each frequency band could provide the reference for land used planning and engineering consideration for seismic safety.

3. RESULTS

The dominant frequency distribution seems can be related to geological or topography distribution. Around 1.2 Hz or less appeared located at basin and plain regions, and 3 to 4 Hz at hill zone (Fig. 3). These results can roughly reflect the deposit thickness at the position of survey points. The dominant frequency distribution and other contours in this study were constructed on GIS (Geographic Information System). So the figure could zoom in to consider the local variations and characteristics, such as Fig. 6 (b) which shows the local site conditions in Taipei basin. The dominant frequency in the Taipei basin is mostly ranging from 1 to 2 Hz reveals soft alluvium deposit of the surface layer.

Except Taipei basin, the other regions in Taiwan also appeared different frequency characteristics. The regions which has dominant frequency occurred below 1.2 Hz are Yilan plain, Chianan plain, and Kaohsiung region. Taoyuan, Hsinchu , Miaoli, and Taidong areas are shown in 2 to 5 Hz. And the highest dominant frequency which is above 6 Hz appeared at Taichung region (Fig. 3).

Fig. 4 shows the comparison between shear-wave velocity from borehole measurements near the strong motion station and the H/V spectral ratio of the nearest microtremor station. First, a clear velocity contrast appeared at about 28 meters depth, the mean shear-wave velocity of this layer is 245.83 m/s. Calculated the 1D resonant frequency by Eqn. 2.1 is 2.27 Hz, and the dominant frequency from nearest microtremor station is 2.19 Hz (For ILA033, Fig. 4(a), (b)). Second, the velocity contrast appeared at about 60 meters and the mean shear-wave velocity is 284.00 m/s. And the resonant frequency is 1.18 which was related to nearest microtremor station (1.36 Hz, for CHY015, Fig. 4(c), (d)). Third, the velocity contrast appeared at about 55 meters and the mean shear-wave velocity is 331.43 m/s. And the resonant frequency is 1.51 which was related to nearest microtremor station (1.83 Hz, for KAU009, Fig. 4(e), (f)). It shows that the dominant frequency of microtremor can reflect the resonant frequency of the surface main layer very well.

The distribution of H/V ratios on different frequency bands (Fig. 5) can be a good reference for engineering application. Generally, the characteristic frequency of a twenty floors building is about 0.5

Hz, and site selection should avoid the high amplification regions in that frequency. So, Fig. 5 can be used for land-used planning.

Wang et al. (2004) used seismic reflection survey to determine the bottom of Sungshan layer in Taipei basin. The isobath of Sungshan layer was shown in Fig. 6(a). This isobath compared very well with the microtremor dominant frequency (Fig. 6(b)).

4. CONCLUSIONS

Microtremer measurement was a convenient technique and the dense survey was widely spread on regions except mountain area in whole Taiwan in this study. The dominant frequency distribution can be related to geological or topography distribution (Fig. 3). And it could have a good agreement compared with the dominant frequency calculated from shear-wave velocity from top layer of borehole measurements (Fig. 4). Due to the borehole measurements are expensive and need lots of time, the microtremor survey can be a useful tool for estimating the dominant frequency of the soil layer. The regional dominant frequency distribution in Taipei Basin (Fig. 6(b)) could roughly fit the depth contour of Sungshan layer from Wang et al. (2004), so microtremor H/V spectral ratio can roughly determine the thickness of the soil layer if the velocity structure was known.

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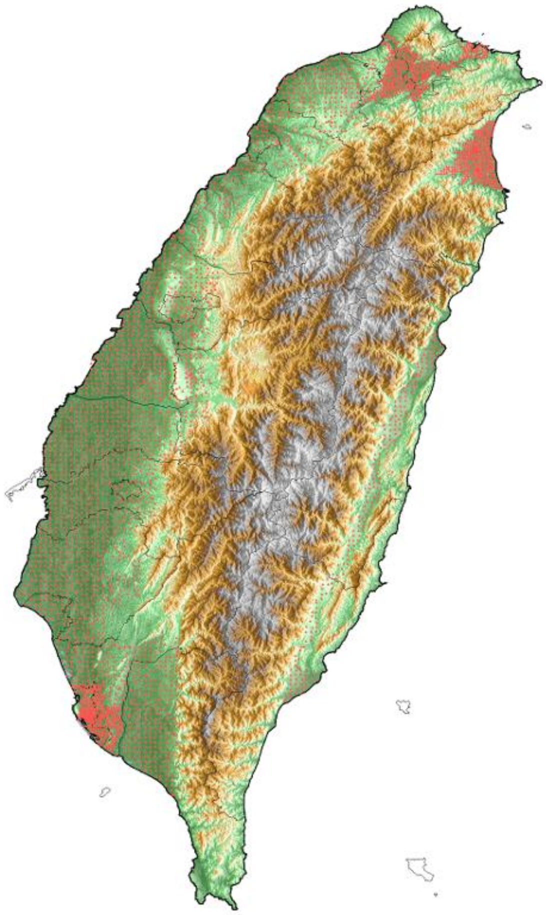


Figure 1. Location of the dense microtremor survey points (red dots) in Taiwan region, station interval is 500 meters to 3 kilometer far.

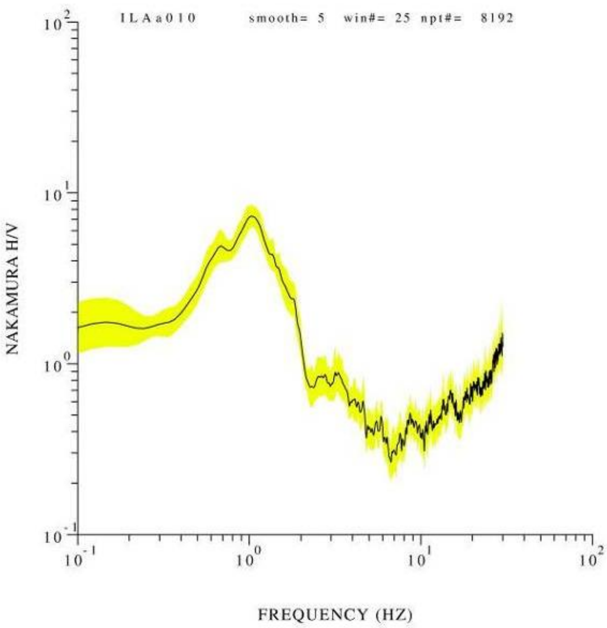


Figure 2. Example of the H/V spectral ratio, which shows the results of station ILAa010. Yellow region shows the one standard deviation area.

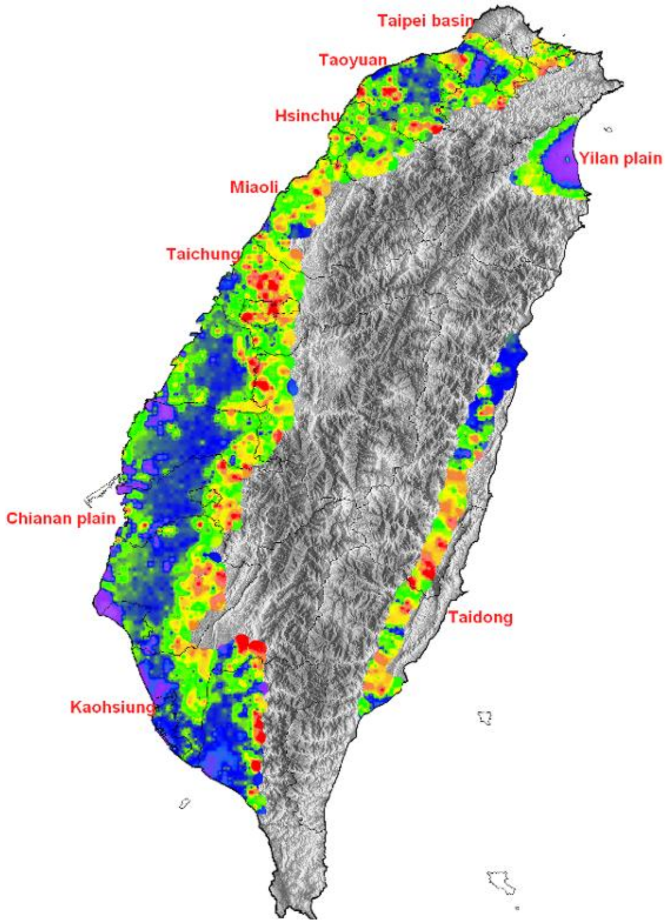


Figure 3. Contour of dominant frequency distribution in the Taiwan region. Color bar shows different frequency values, monochromatic background shows the topography.

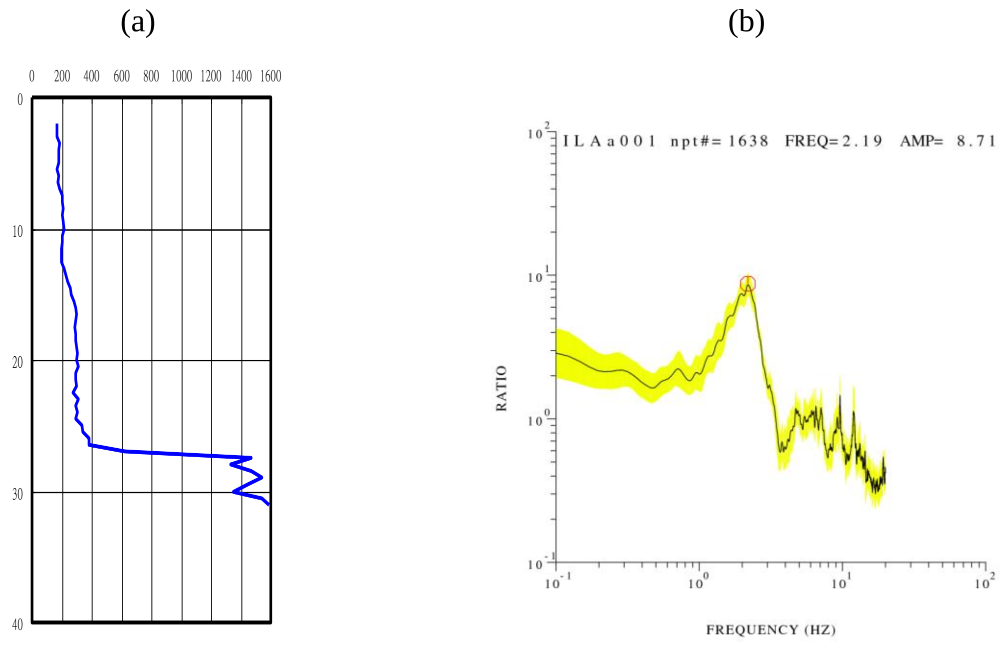


Figure 4. (a) Shear-wave velocity at station ILA033, horizontal axis is velocity (unit in m/s) and vertical axis shows depth from ground surface (unit in m). (b) Microtremor H/V spectral ratio of station ILAa001 which is near the station ILA033, the red circle shows the dominant frequency.

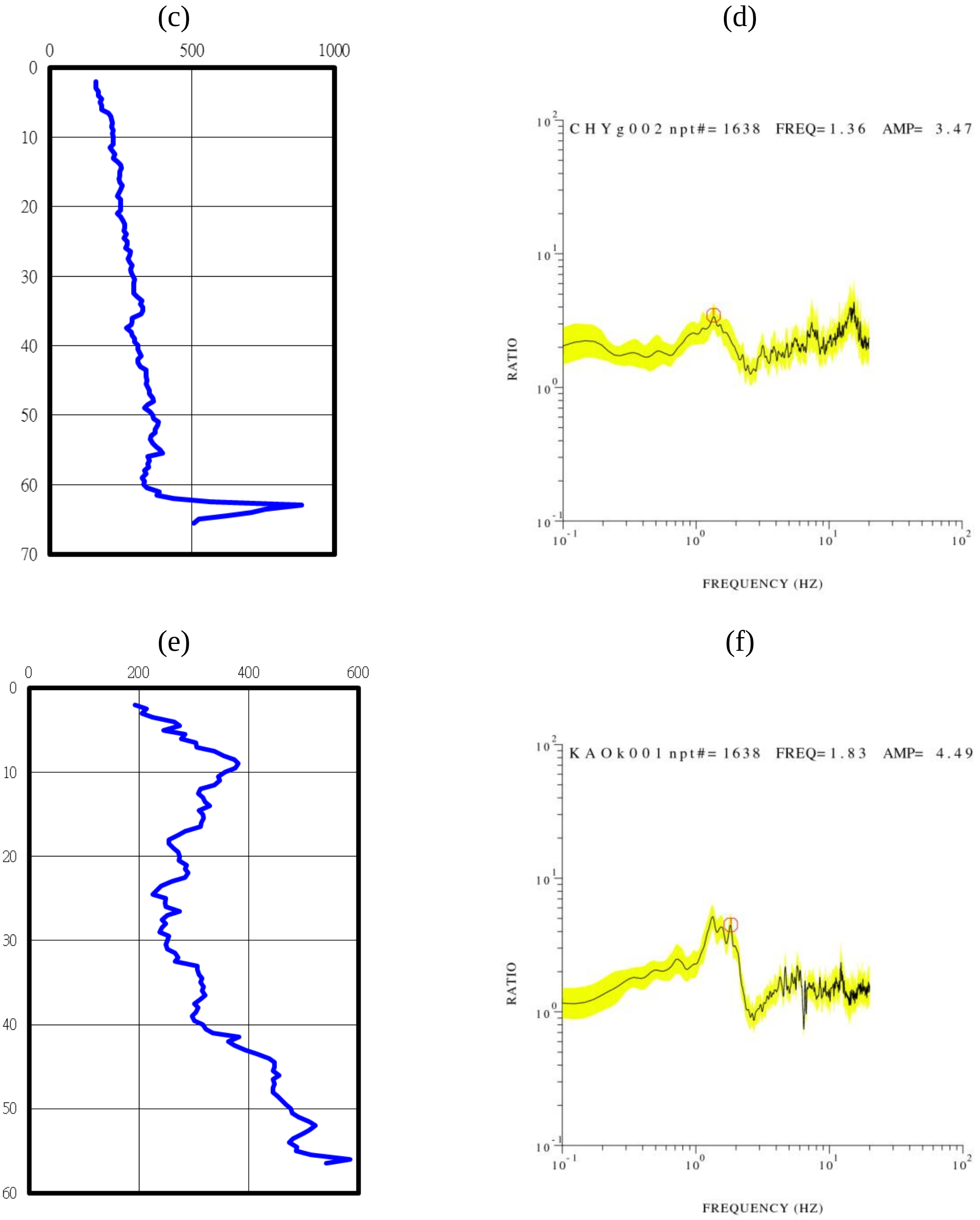


Figure 4(continue)**.** (c) Shear-wave velocity at station CHY015, horizontal axis is velocity (unit in m/s) and vertical axis shows depth from ground surface (unit in m). (d) Microtremor H/V spectral ratio of station CHYg002 which is near the station CHY015, the red circle shows the dominant frequency. (e) Shear-wave velocity at station KAU009, horizontal axis is velocity (unit in m/s) and vertical axis shows depth from ground surface (unit in m). (f) Microtremor H/V spectral ratio of station KAOk001 which is near the station KAU009, the red circle shows the dominant frequency.

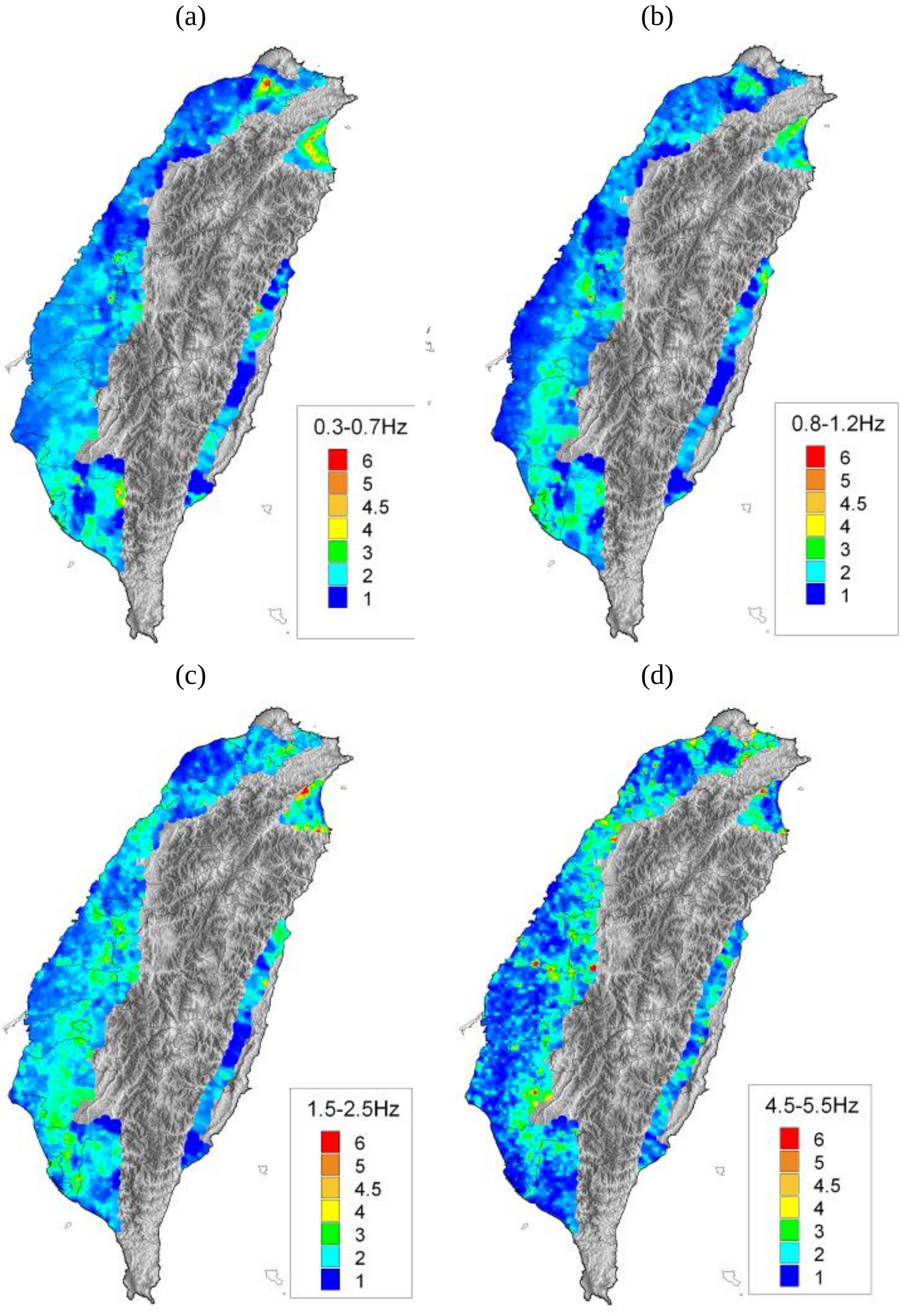
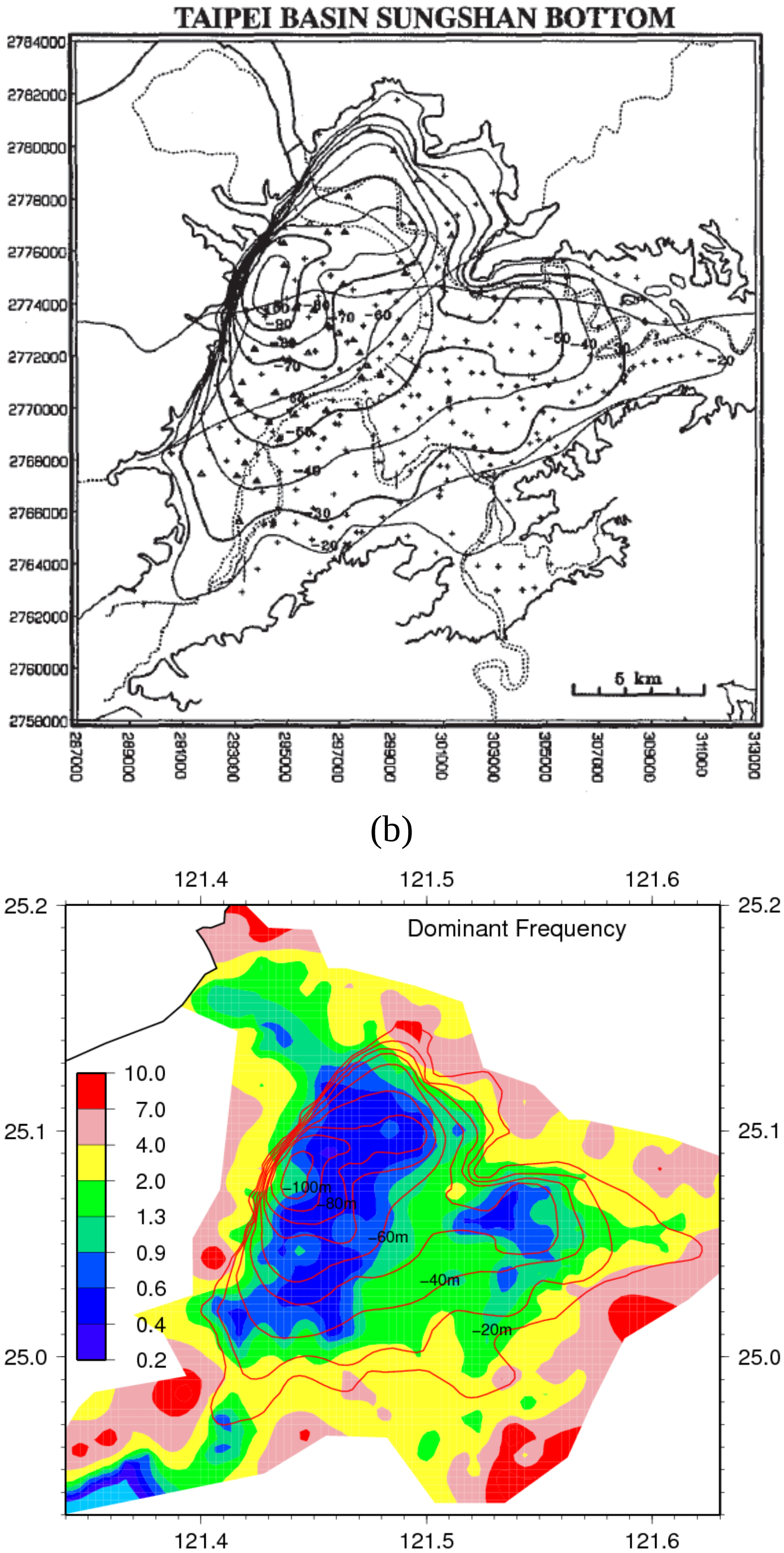


Figure 5. (a) Contour of the H/V ratios at 0.3-0.7 Hz. (b) Contour of H/V ratios at 0.8-1.2 Hz. (c) Contour of H/V ratios at 1.5-2.5 Hz. (d) Contour of H/V ratios at 4.5-5.5 Hz.

(a)



(b)

Figure 6. (a) Isobath of Sungshan layer bottom in the Taipei basin (Wang et al., 2004). (b) Comparison of the dominant frequency distribution with Isobath of Sungshan layer's bottom.