SITE RESPONSE CHARACTERISTICS OF H/V SPECTRUM BY MICROTREMOR SINGLE STATION OBSERVATIONS AT PALU CITY, INDONESIA

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Abstract

In this study, we estimated predominant period of an H/V spectrum in Palu City, Indonesia, by using microtremor single station observations. Sulawesi Island, eastern Indonesia, is located at the junction between the converging Pacific-Philippine, Indo-Australian Plates and the Eurasian Plate. One of the major structures in Central Sulawesi is the Palu-Koro Fault system, which extends NNW-SSE direction and cross-cuts Sulawesi along more than 300 km from the North Sulawesi trench passing southward through Palu Bay then turn to the southeast, connecting to the Matano and Lawanopo Faults and further eastward both faults join to Tolo trench. Several earthquakes have been known along Palu-Koro Fault system such as Gimpu earthquake (1905), Kulawi earthquake (1907), Kantewu earthquake (1934), and offshore Donggala earthquake (1968) which caused tsunami that destroyed 800 houses and killed 200 people at Donggala district. Palu City, located at the northern tip of Palu depression, is a capital of the Central Sulawesi Province. It is located in the active seismic zone of the Palu-Koro fault. Spectral ratios for horizontal and vertical motion (H/V) from single-station microtremor records were used to identify the predominant periods of the ground vibrations. Understanding the parameters of predominant period[s] and seismichazard is important for mitigation and environmental planning of the Palu region.
Keywords: *H/V spectrum, predominant period[s], microtremor single station observation*

1 Introduction

One of the major active structures in Sulawesi is the left lateral Palu-Koro Fault, which extends NNW-SSE direction and cross cuts Central Sulawesi. This fault connects to the North to the North Sulawesi trench and to the South, then turns to South East and connects with both Matano and Lawanopo sinistral Faults (Hamilton, 1979). Further eastward, both faults join into Tolo trench (Figure 1). Based on earthquake catalog from USGS and Indonesia Institute of Meteorology and Geophysics, during period of 1968 to 2012, a hundred earthquakes with magnitude of 3–7 Richter were recorded in Sulawesi area (Figure 2). These earthquakes clustered at northern arm of Sulawesi, where the active tectonic plates meet. In the Central Sulawesi, a lot of earthquakes occured in the zone associated with the Palu-Koro and Matano faults. Several better-known earthquakes along the Palu-Koro fault occured at Gimpu–1905, Kulawi–1907, Kantewu–1934 and offshore Donggala–

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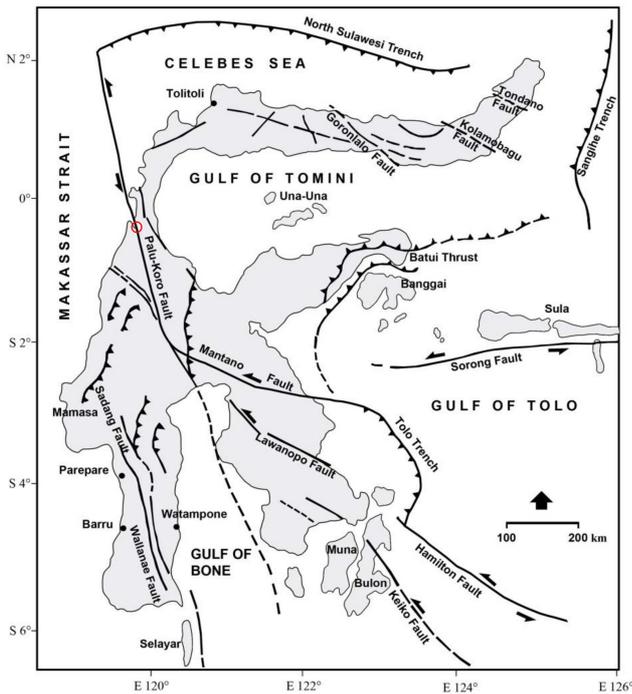
Figure 1: Tectonic map of Sulawesi (Priadi, 1993). Red circle: Palu depression area.

1968. The last earthquake with the focal depth of 23 km caused tsunami wave up to 10 m high. It has destroyed 800 houses and killed 200 people at Donggala district.

City of Palu, located at northern tip of Palu depression, is a capital of the Central Sulawesi Province. As a capital of province, Palu will be a center of development where population growth by urbanisation usually increases rapidly. Considering the seismic activity along the Palu-Koro fault zone, understanding the parameters of predominant periods and seismichazard is important for mitigation and environmental planning.

In recent years, microtremor observations have become popular for the purpose of investigating soil structure because they do not require much manpower and cost. Microtremor is a small ground vibration excited by artificial sources or natural phenomena such as factories, traffic, wind, waves, etc. As the vibration propagates through the ground surface, the surface waves such as the Rayleigh and Love waves are dominant.

In this study, Palu, where a large earthquake is expected in the near future, is considered to be a target area. We carried out higher density single-point observations. Based on the observed data, we calculated the distribution of predominant Rayleigh wave.

2 Geometry of Palu depression

Geometry of the northern part of Palu-Koro Fault system shows an asymmetric graben called Palu depression which is up to 7 km wide bordered by N-S orientation, up to 60 m high steep triangular facets and truncated alluvial fans at West side, and gently step faults at East side along approximately 20 km length from Palu bay to the north and Gumbasa valley to the south.

The topography of the Palu region in detail become firstly important to observe and to analyze. Topographic map of 1:50000 scale and digital elevation model (DEM) from SRTM with 30 m resolution can be combined in order to determine structural lineaments (Figure 3).

3 Microtremor single station observations

A microtremor is a very small ground motion that can be recorded on the ground surface. It can be produced by a variety of excitations (eg., wind, traffic, breaking sea waves), A full microtremor record can be described by one vertical and two horizontal components. Our analysis was conducted by using the recorded microtremor. First, the horizontal and vertical spectrum ratios (HVSR) were computed for all of the observation sites. The peak period of the HVSR is known to correspond to the resonant period of the site.

A three-component accelerometer with GPL-6A3P data logger (produced by Akashi Co. Ltd.) was used. The number of single-point observations was 151 (Figure 4). The sampling frequencies were 100 Hz or 500 Hz and the observation times were 10 to 15 minutes.

4 Predominant period of H/V spectra

The spectral ratio of horizontal and vertical motion obtained by microtremor observations is
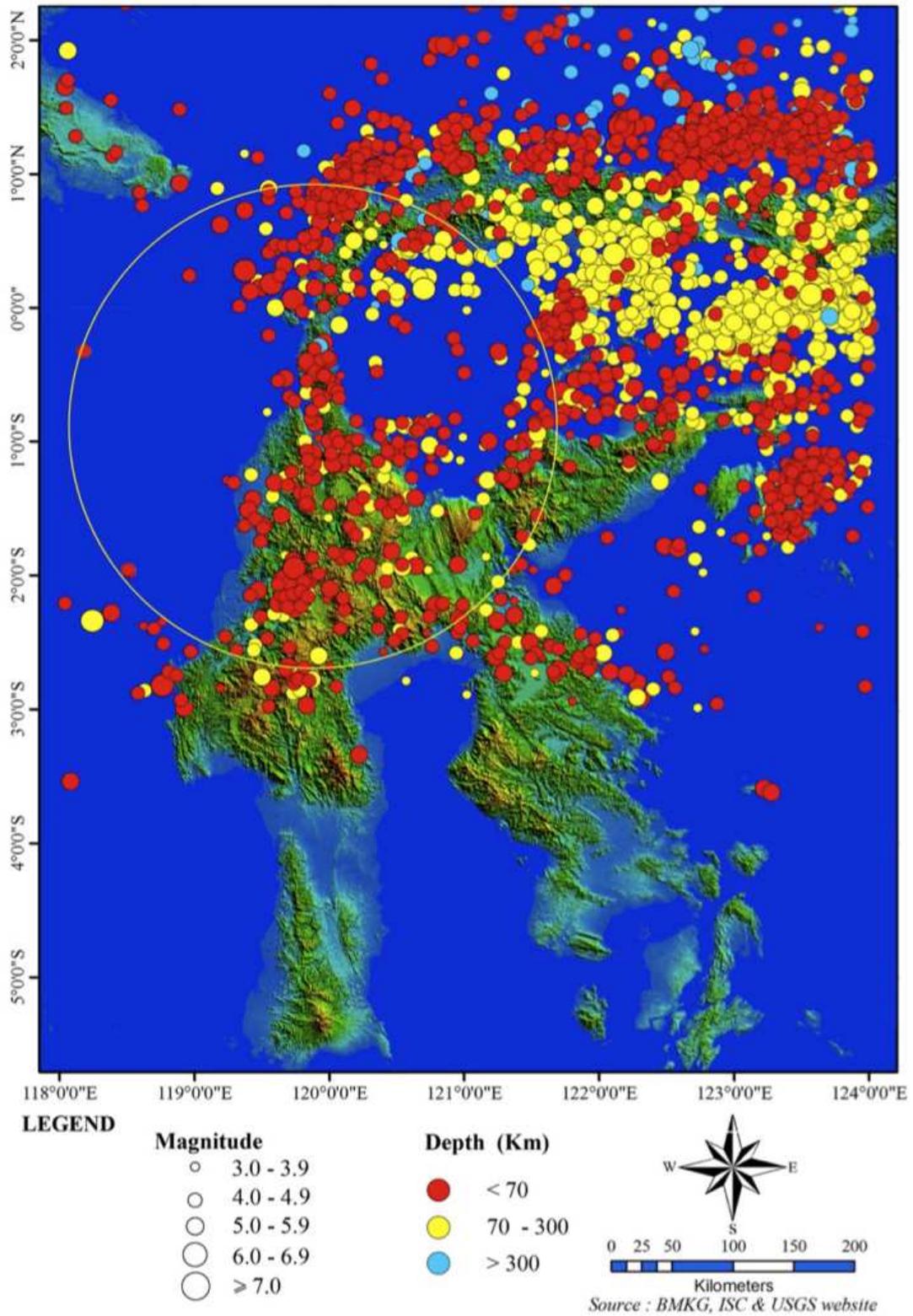
Figure 2: Epicentral distribution of some important earthquakes around Palu province.
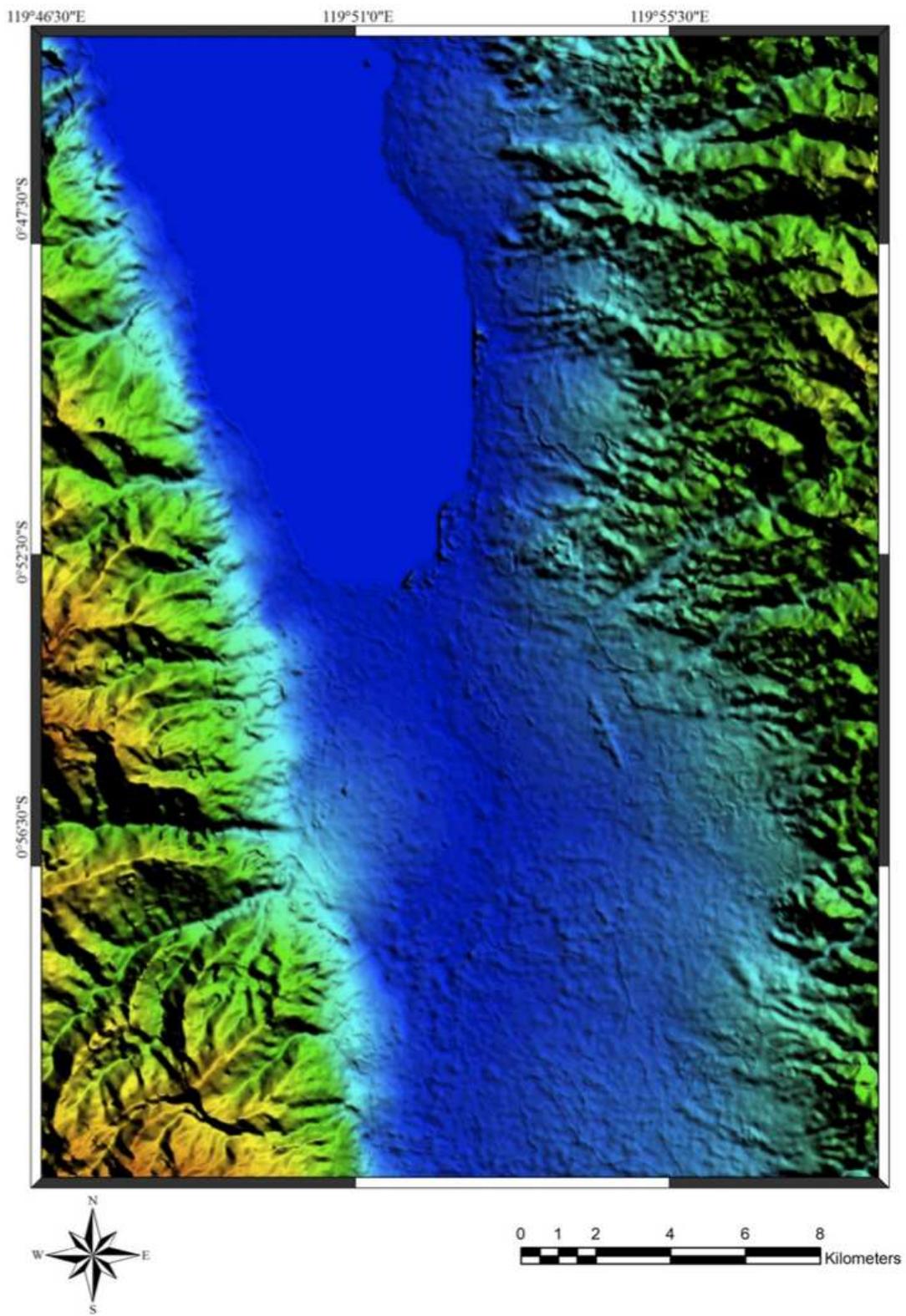
Figure 3: DEM of Palu area.
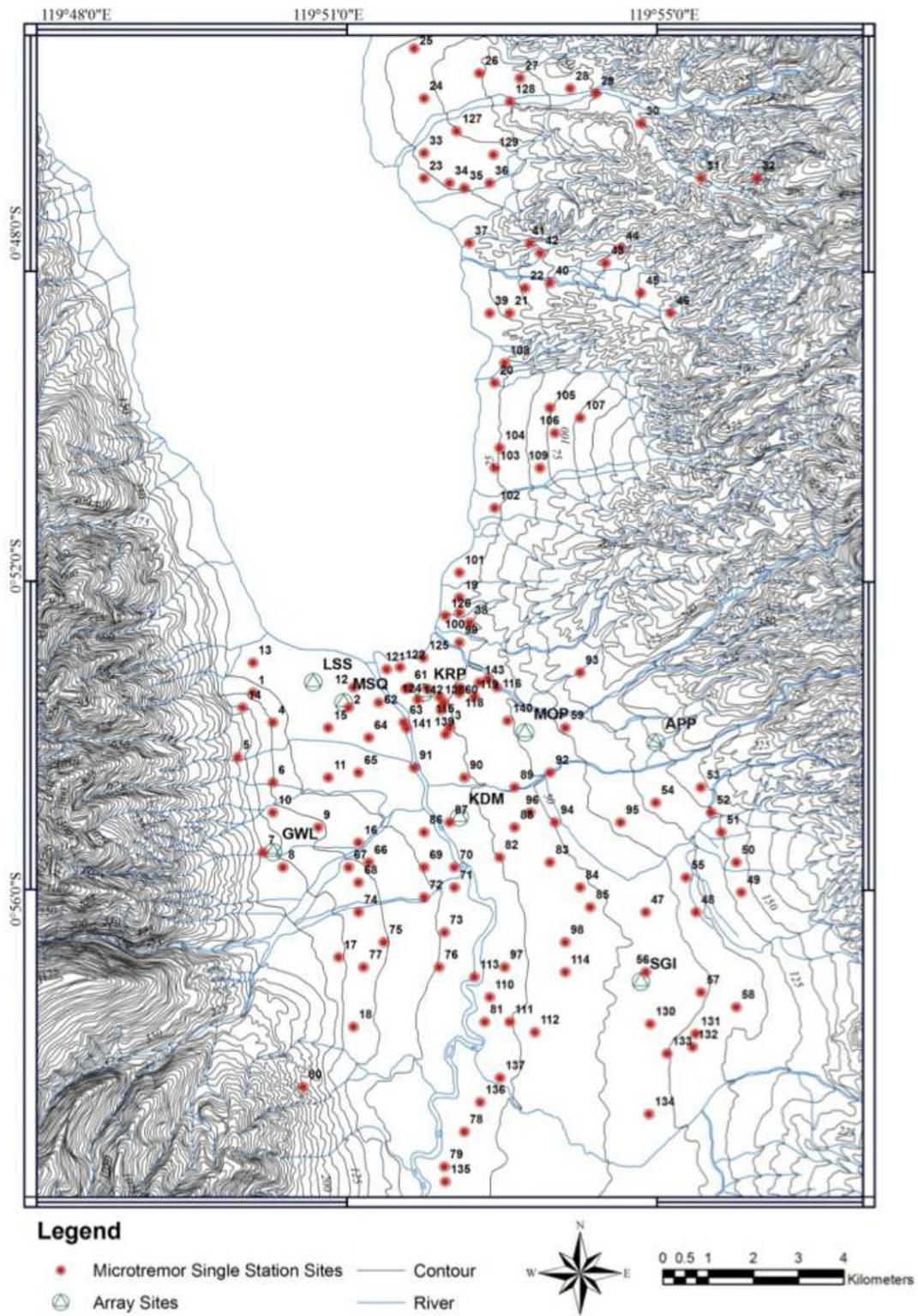
Figure 4: Location of the microtremor observation sites.

called the H/V spectrum. The predominant period of an H/V spectrum is thought to be equivalent to the predominant period of the ground directly beneath the site. H/V spectra at each site in the target area were calculated. We classified the H/V spectra calculated into three types according to the shape of the spectra (Figure 5).

Type A: those with short period peak (Figure 5(a))

Type B: those with long period peak (Figure 5(b))

Type C: those without clear peaks (Figure 5(c))

Distinct peaks express layers characteristics in which the shear wave velocity is quite different. According to this interpretation, the lower and higher periods in Type A represent the effects from deep and shallow soil layers, respectively. In Type B, the difference between the two layers is not marked and the effect of one layer is absorbed into that of the other layer. Type C is an observation site that has hard soil or did not work well. Thus, we established the data for both long and short predominant periods. Although the predominant period does not always indicate the characteristics of an individual layer because typically the actual shaking mode of the ground is complex, we assumed that the long and short periods reflected information from each layer.

Although there are 151 observation points, the points are not adequate to cover all the target area if each value of the predominant period obtained is considered to be a realization of a stochastic random field. Space interpolation is conducted by ordinary Kriging technique. The results are shown in Figure 6. The predominant periods of 1.5–2.0 seconds were on the alluvial fan area. The spatial correlations between predominant periods on the Westside Mountain (which slope is steep) are shorter than those in the eastside mountain and change more rapidly.

5   Conclusions

Our observations and analysis provide useful and practical data for earthquake disaster mitigation in Palu. The procedure employed and conclusions obtained in this study area are as follows.

1. Microtremor observations were carried out for constructing a subsurface ground model in Palu. Single-point observations were conducted at 151 sites which covered almost the whole city area.
2. H/V spectra were calculated at all the single-observation sites and a distribution of predominant periods was obtained.
3. The Kriging method can be used for the interpolation of subsurface information such as predominant period and shear wave velocity.
4. The predominant periods of 1.5–2.0 seconds were on the alluvial fan area.

Acknowledgements

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(a) short period peak

(b) long period peak

(c) without clear peak
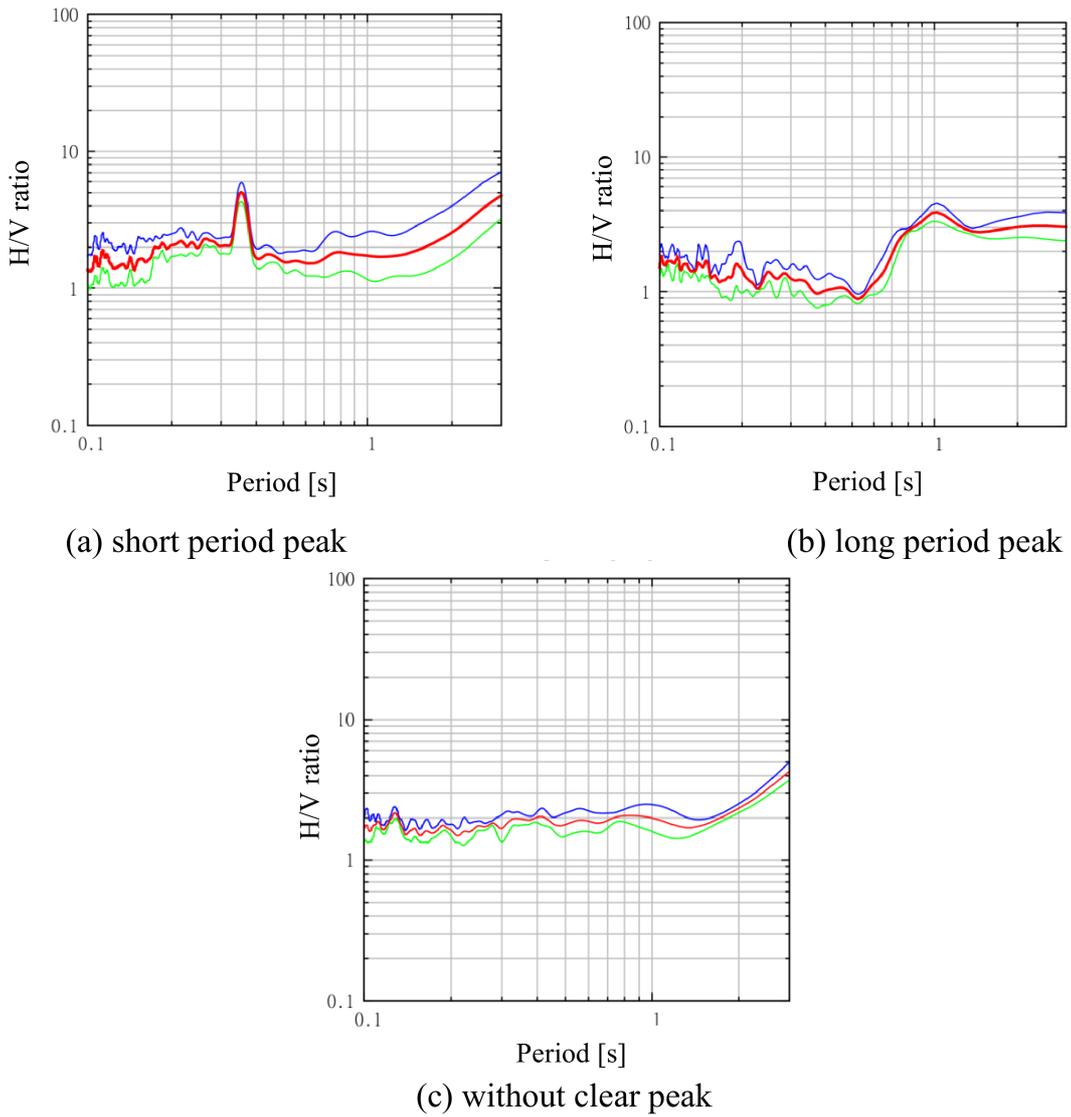
Figure 5: Example of the H/V spectrum ratio (mean value and 1 deviation).
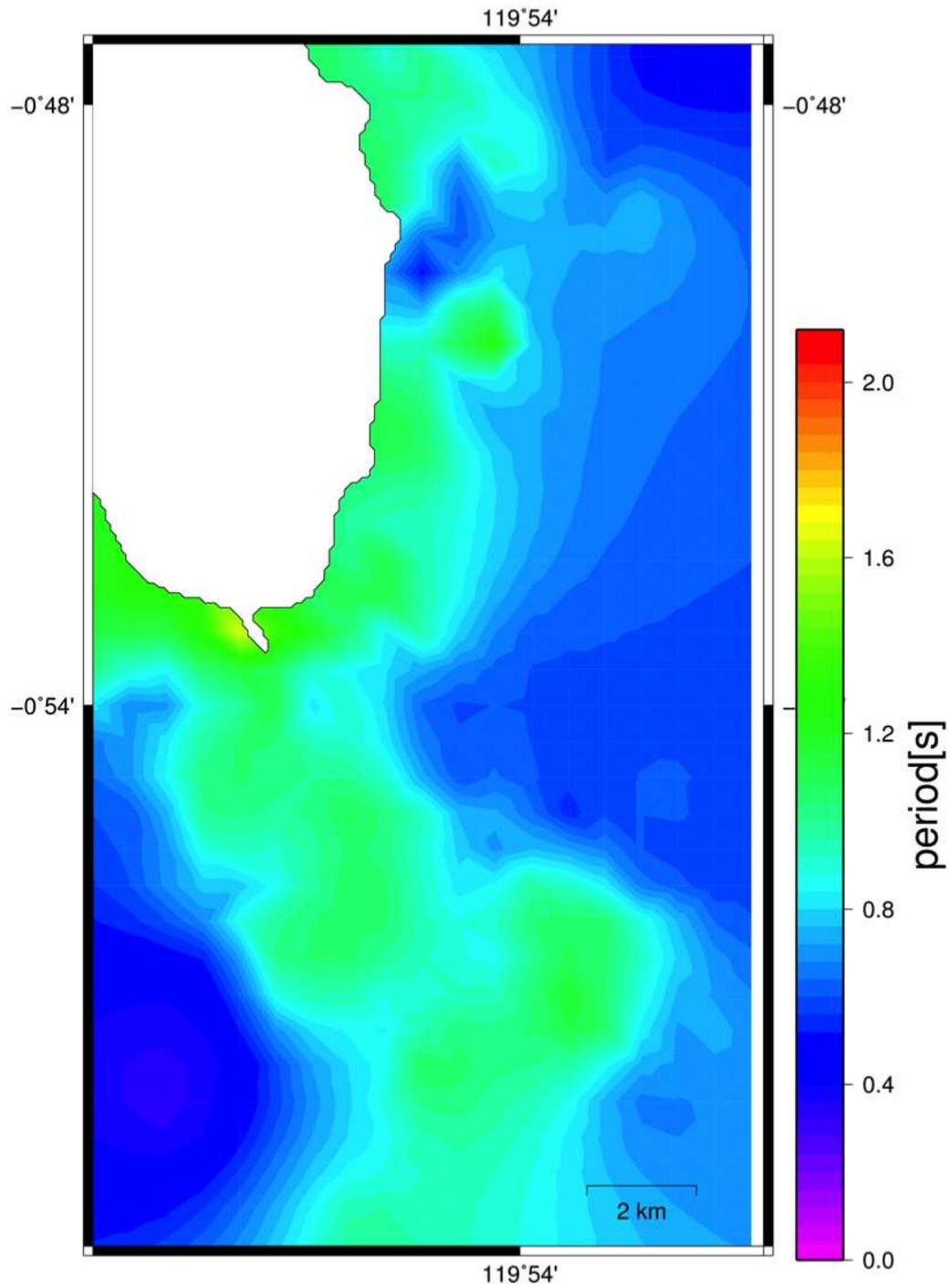
Figure 6: Spatial distributions of longer and shorter predominant periods, Ts.

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