RESULTS OF THE INFRASONIC SITE SURVEY AT CTBT STATION IS59, HAWAII

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ABSTRACT

An infrasonic site survey for station IS59 in the island of Hawaii was performed from June 2 to June 16, 1999. Instruments were deployed at two prospective sites. The first site, in the Kulani forest, was located at a mean elevation of 1.7 km on the windward side of the island, approximately 10 km downhill from the Northeast rift zone of Mauna Loa Volcano. The second site was located in the Kahalu'u forest at a mean elevation of 1 km on the leeward, drier side of the island. Comparison of infrasonic noise levels recorded at the candidate sites demonstrated that the Kahalu'u forest was the quieter of the two sites.

Key Words: Infrasound, site survey, IS59, Hawaii

OBJECTIVE

The primary purpose of the site survey at Hawaii is to determine a suitable location for a CTBT infrasonic array (IS59) with the lowest possible background noise level. This paper presents a comparison of infrasonic noise levels observed at two candidate sites in opposite sides of the island.

RESEARCH ACCOMPLISHED

1. Introduction

A site survey for infrasound array station IS59 in the International Monitoring System (IMS) was carried out on the island of Hawaii over the period from June 2 to June 16, 1999. The survey was conducted by the University of Hawaii in collaboration with the Infrasound Section of the International Monitoring System Division of Comprehensive Nuclear-Test-Ban Treaty Organization. The survey was conducted in accordance with the infrasound site survey requirements described in the Preparatory Commission guidelines.

Hawaii is the largest island in the chain with dimensions of approximately 150 km (N to S) by 130 km (E to W), and a total land area of 10,433 km^2. A map showing the topography of the island is shown in Figure 1. The IMS coordinates are within 3 km of the Kulani site (Figure 2). The Kulani survey area is at high elevation (1.7km) in the windward, rainy side of the island, hosts a variety of endangered flora and fauna, and is close to two of the most active volcanic areas in the world. The Kahalu'u survey area (Figure 3) is at a lower elevation (1 km) in the leeward, dry side of the island, where trade winds are absent. Volcanic risk at the Kahalu'u site is minimal.

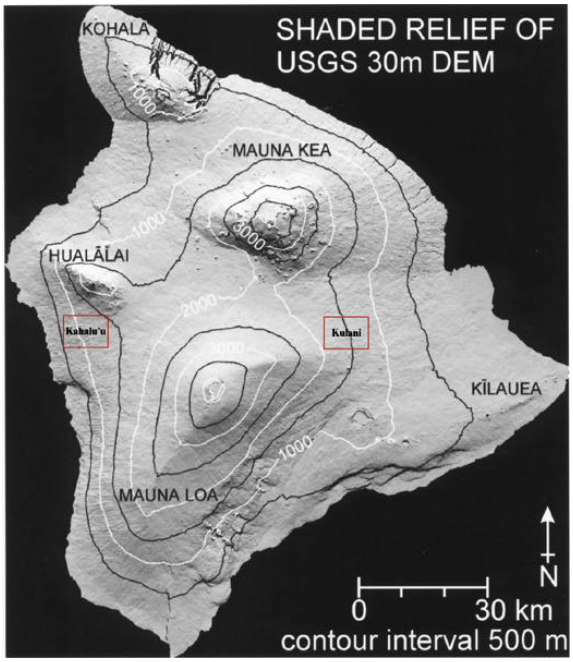

Figure 1. Shaded digital elevation map of Hawaii, showing the extreme topography of the island and the five main volcanoes. The two survey sites in the Kulani and Kahalu'u forests are demarcated by boxes. The IMS coordinates for IS59 (19.6N, 155.3W) are contained within the Kulani area. (DEM image provided by Scott Rowland, University of Hawaii, Manoa)

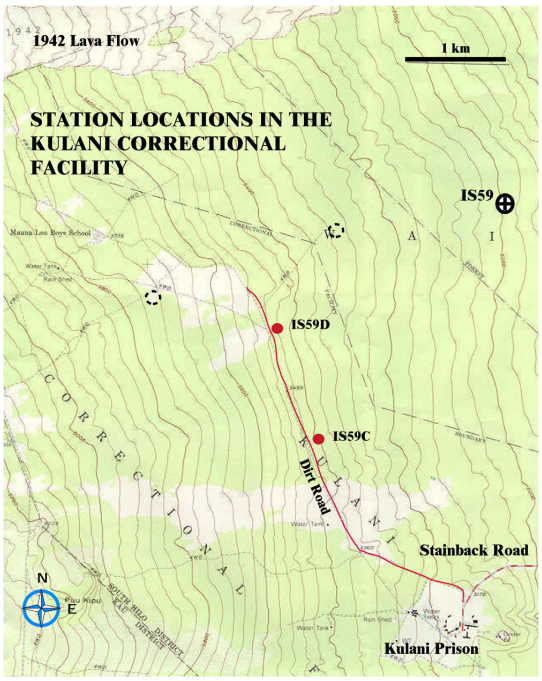

Figure 2. Site survey area on the Kulani Correctional Facility, and designated station coordinates for IS59. Solid dots mark the locations of survey stations, and dashed dots represent two additional elements required to complete a 4-element array.

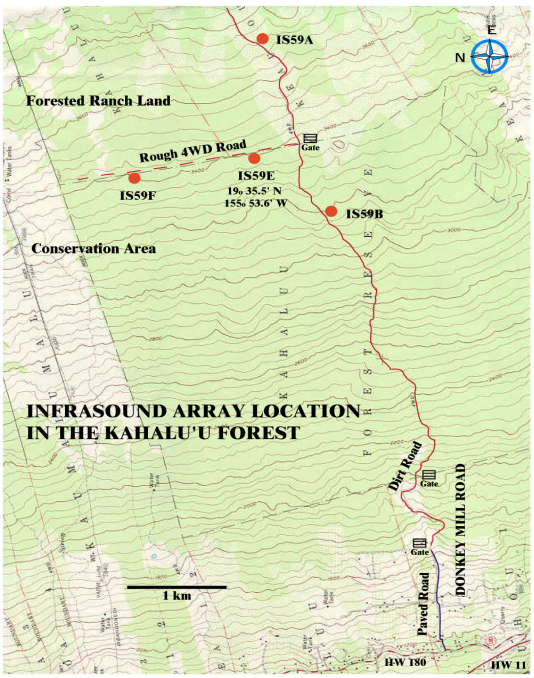

Figure 3. Site survey area on the Kahalu'u Forest. Solid dots mark the locations of survey stations.

2. Experimental Equipment and Procedure

Observations of background micropressure noise, wind speed, wind direction and temperature were made using four sets of Orion portable field recorders, Vector Instruments anemometers, Skye Instruments temperature sensors and MB2000 microbarometers. Unless otherwise stated, all microbarometers had porous hoses. The campaign strategy consisted of two distinct stages. The initial stage involved the deployment two stations in the Kulani site and two stations in the Kahalu'u site in order to record simultaneously at both prospective sites. Comparison of the infrasonic data recorded during this first stage of the survey showed that the Kahalu'u site provided a better location for IS59. This decision led to the second stage of the campaign, where all stations were established in the Kahalu'u site and located as close as possible to the proposed IMS array configuration.

From June 1 to June 2 the absolute pressure microbarometers were reset for sea level, and a huddle test was performed to check the sensors and digitizers. On June 2, three stations were deployed at Kulani (Figure 2): one with porous hoses (C), a second station (H) with an open port co-located with station C, and a third station (D) at a different location. On June 3, station H was removed, and stations C and D were left to record continuously until June 8. On June 4, two stations were installed at Kahalu'u (stations A and B, Figure 3), which recorded continuously until June 16. On June 7, data was downloaded from all Kahalu'u and Kulani stations, and a comparison of the noise levels demonstrated that Kahalu'u was quieter. On June 8 the two stations in Kulani were removed, and an open-port microbarometer (K) was co-located with site A in Kahalu'u. On June 9, site K was removed, and two new stations were deployed in the Kahalu'u site (stations E and F). A 4-element array with an aperture of approximately 1.85 km recorded continuously from June 9 to June 16 in Kahalu'u.

This paper describes the results of the infrasonic noise survey during the fist part of the filed campaign, when simultaneous measurements were made at the Kahalu'u and Kulani sites from June 4 to June 8, 1999. During this time period, stations A and B recorded in the Kahalu'u forest while stations C and D recorded in the Kulani forest.

3. Results of Noise Survey

3.1 General Description of Noise Characteristics

The average infrasonic noise characteristics in Hawaii will be determined by the diurnal heating and cooling cycle, the thermal interaction between the relative large landmass of the island and the ocean, and the flow of the ever-present Northeasterly trade winds around the extreme topography of the island. Since the Kahalu'u forest is completely protected form the trade winds and incoming weather by Mauna Loa, Mauna Kea, and Hualalai Volcanoes, this site is expected to be acoustically quieter than the Kulani site. The following section illustrates in more detail how this intuitive argument is corroborated by infrasonic data.

3.2 Evaluation of Noise Levels

The noise characteristics at individual potential array sites may be evaluated by comparing the power density spectra of micropressure data from the various sites recorded over the same time interval. Most of the analysis described in this report has, been carried out using a modified version of MATLAB programs developed by Dr. Manfred Henger and Dr. Gernot Hartmann (Henger et al., 1998). Power spectra, in Pa^2/Hz, are estimated by Welch's method using a non-overlapping Hanning window of 4096 samples (204.8 s) and averaged over an integer number of hours.

During the IS59 site survey, average wind velocities were lower than 1 m/s. Due to the unresponsiveness of the anemometers to such low-wind conditions, wind measurements were not useful during most of the survey.

3.3 Daytime Noise Conditions

Averaged power spectral density for the 12 hours of the day (6AM to 6 PM local time) of June 5 and 6 are shown in Figure 4 for all sites. The microbarom peak at approximately 0.23 Hz is present at both the Kahalu'u and Kulani stations, although the microbarom peak appears slightly stronger in Kulani. Array processing of microbarom signals recorded during the second stage of the campaign suggest that this microbarom frequency may be associated with swells driven by the ever-present Northeasterly trade winds. This would be consistent with the higher microbarom peak observed at Kulani, on the Eastern side of the island. For frequencies between 0.2 Hz and 2 Hz, noise levels have similar slopes at all stations, but levels are higher by a factor of two or more at the Kulani site. For frequencies below 0.2 Hz, the difference between the Kahalu'u and Kulani sites is more severe, with noise levels about an order of magnitude higher at the Kulani site. No clear interpretation has been given for this difference in spectral levels at low frequencies, although it is possible that Mauna Loa and Mauna Kea volcanoes block westward-propagating eddies that may travel with the trade winds.

A small spectral peak near 0.12 Hz was observed at the Kahalu'u site on June 6. This peak, well below the noise floor of the Kulani site, vanished after a few days. Analysis of secondary microbarom peaks observed during the second stage of the site survey suggest that these secondary peaks may be associated with low-pressure systems in the Pacific Ocean.

3.4 Nocturnal Noise Conditions

Averaged power spectral density for the 12 hours of the night (6PM to 6 AM local time) of June 5 and 6 are shown in Figure 5 for all sites. Spectral features are similar those of Figure 4 in the frequency band between 0.2 Hz and 2 Hz, with small variations in the noise levels. At frequencies below 0.2 Hz, noise levels are slightly reduced in Kulani during the night, although they are still higher than at Kahalu'u. On June 6, the slope of the mean nocturnal spectrum at Kahalu'u changed noticeably when the 0.01 Hz level dropped. Diurnal noise levels fluctuations at the Kahalu'u site are most pronounced in the 0.01 to 0.1 Hz band, as will be discussed in the next section.

3.5 Mean, Maximum, and Minimum Noise Levels

Averaged power spectral density for all 24 hours of June 5 and 6 are shown in Figure 6 for all sites. It is evident that the Kahalu'u stations have lower average noise levels than the Kulani stations. The diurnal variability in noise levels for all sites during the 24 hours of June 6 are shown in the upper panel of Figure 7. Each gray line represents a one-hour average, and the solid line represents the mean spectrum, as shown in Figure 6. Figure 7 shows that he Kulani site does not show much diurnal variability, possibly because its noise characteristics are determined by the dominant trade winds, which are quite stable. Maximum and minimum noise levels at Kulani may correspond to the evening slackening of the trade winds. In contrast, the Kahalu'u site shows a strong variability for frequencies below 0.1 Hz. Since the trade winds are completely absent in the Kahalu'u site, it is likely that its noise characteristics are determined by local effects which may be driven by ocean-land thermal interaction. The relatively small variability and low noise floor of high-frequency noise levels at all stations reflects the low wind conditions encountered at both sites.

The lowest noise level shown in the first panel of Figure 7 occurred in Kahalu'u between 0 and 2 UT of June 6, which corresponds to 2 and 4 PM local time of June 5. It is possible that during this time, clouds and mist forming in the mountain created a stable, thermally equilibrated layer with no wind. However, the rogue spectral peak at 0.12 Hz prevented this episode from producing the lowest levels. The lowest noise levels observed during the site survey occurred on June 11, 1999, after the installation of a 1.85 km aperture array in the Kahalu'u site (Figure 3). The minimum noise levels for all the array elements are shown on the lower panel of Figure 7. The times correspond to the seven-hour period between 5 PM and midnight. The formation of a stable layer on the mountain slopes during the late afternoon may also explain the exceptionally low noise levels at this site. Because of the low noise floor, it was possible to observe the formation of a secondary microbarom peak, which steadily grew in amplitude until the end of the survey

(June 16). This secondary microbarom peak may be associated with the formation and evolution of a low pressure system in the Aleutian arc.

3.6 Summary of Infrasonic Noise Conditions

The analysis of the survey data has shown that noise conditions at Hawaii exhibit some diurnal variations, specifically in the Kahalu'u site. Most of this variability occurred at frequencies lower than 0.1 Hz, and may be driven by local effects. The survey has shown that noise levels are lower at the Kahalu'u site, where an infrasound station with very good detection capability can be established.

CONCLUSIONS AND RECOMMENDATIONS

The site survey demonstrated that the Kahalu'u site is superior to the Kulani site for the installation of IS59. The Kahalu'u site has a lower volcanic risk, is less humid, has less environmental impact and land access restrictions, and most importantly, has lower infrasonic noise levels than the Kulani site. The installation of IS59 in the Kahalu'u forest is recommended.

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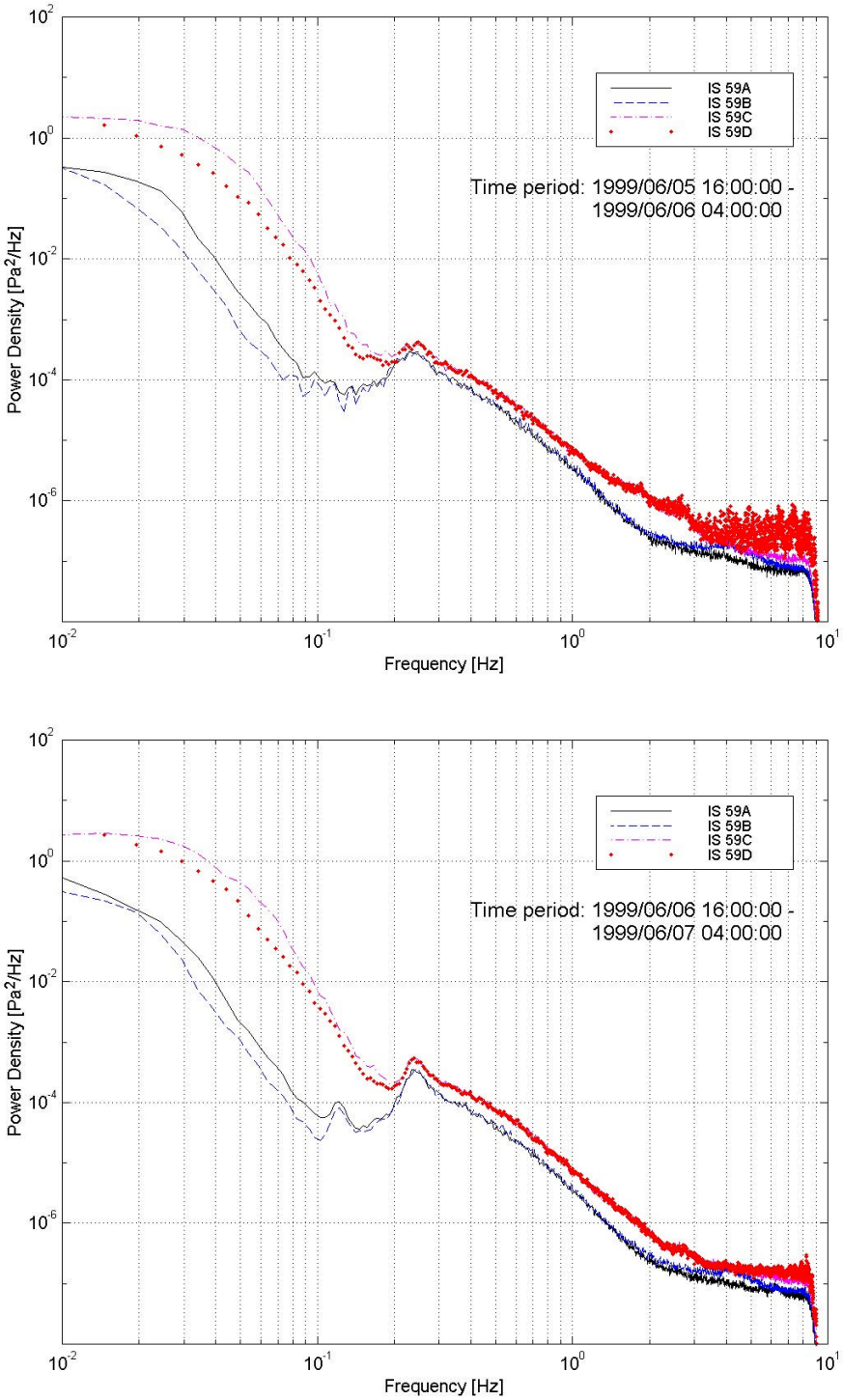

Figure 4. Power spectral density as a function of frequency for the Kahalu'u and Kulani sites averaged from 16 to 4 UT, or 6 AM to 6 PM local time (daytime). The Kahalu'u stations are quieter at all frequencies.

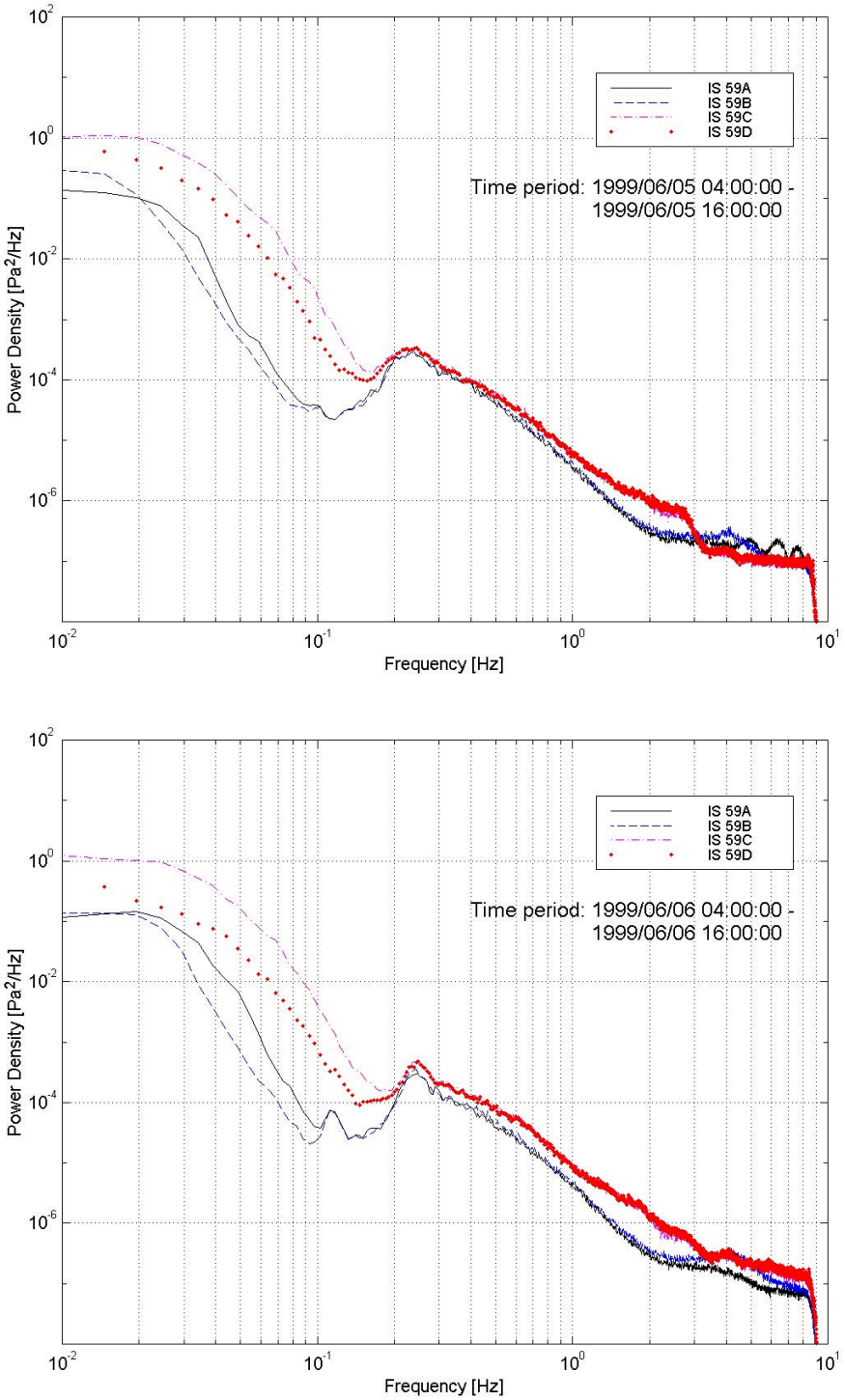

Figure 5. Power spectral density as a function of frequency for the Kahalu'u and Kulani sites averaged from from 4 to 16 UT, or 6 PM to 6 AM local time (night time). The Kahalu'u stations are quieter at all frequency lower than 3 Hz. The sharp change in slope at 3 Hz in the Kulani stations suggests a local source of low-frequency noise.

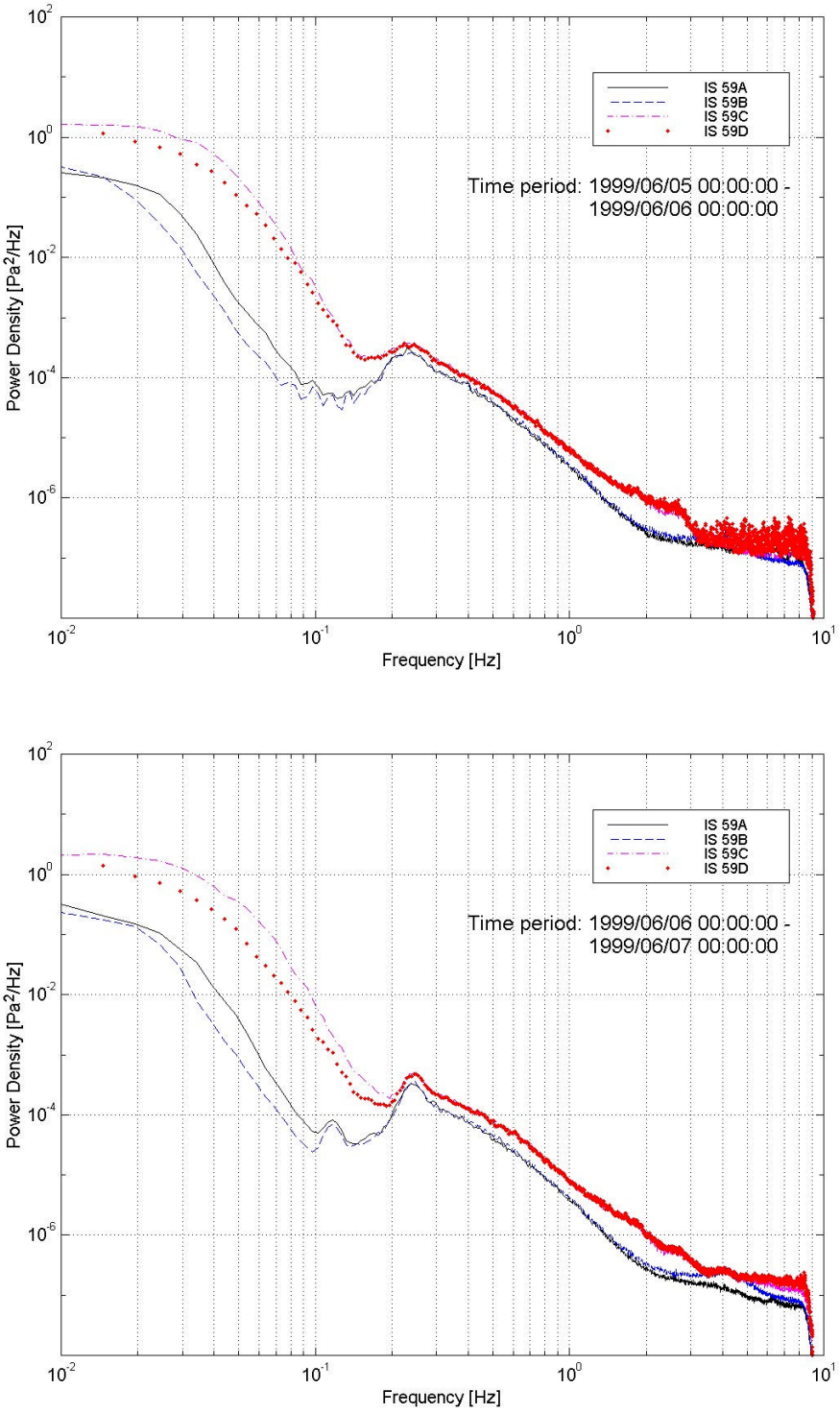

Figure 6. Twenty-four hour power spectral density averages for all sites on June 5 (upper panel) and June 6 (lower panel). The Kahalu'u sites are quieter at all frequencies.

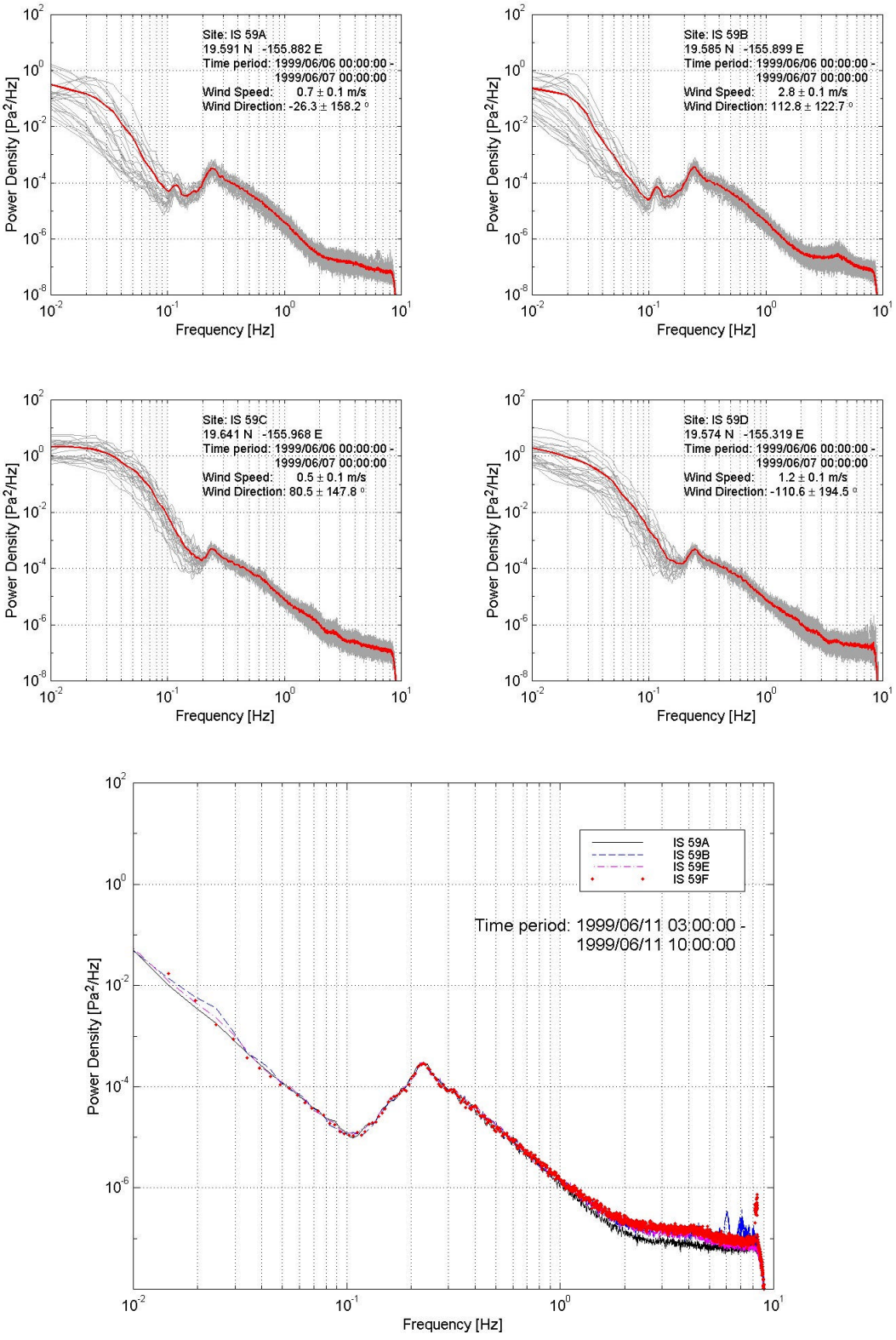

Figure 7. The upper panel shows the range of micropressure noise levels observed during the 24 hours of June 6. These levels are representative of the maximum and minimum noise levels observed from June 3 to June 8, 1999. The lowest noise levels in this time period occurred from 0 to 2 UT. The lowest noise levels recorded during the site survey occurred in the Kahalu'u forest on June 11, and are shown in the lower panel. After June 12, a low pressure system in the Aleutian arc increased the microbarom peak to a peak level of approximately 2×10^{-3} Pa^2/Hz at 0.15 Hz.