

2023 Kīlauea Horizontal-Component Signal/Noise Assessment of a Large Three-Component Nodal Array

immediate

Supplemental Data Files

This supplement provides four comma-separated values (CSV) files that identify station subsets for initial analyses (e.g., S-wave arrival detection and picking, moment tensor analyses, S-wave attenuation tomography, and interferometry) by listing frequency bandwidths for stations with sufficient average horizontal-component signal-to-noise ratio (S/N) to consider for such analyses. The files are:

`2023_kilauea_3d_most_possibly_useable_horizontal_station_list_to_1p2Hz.csv`

This CSV file lists 1,099 three-component (3C) stations that generally have good horizontal-component and horizontal-to-vertical (H/V) S/N for frequencies between 0.25 Hz and 1.2 Hz. It is intended primarily for interferometric investigations. Approximately 375 stations in this list are wind sensitive, with wind-speed-dependent horizontal-component and H/V S/N decreasing at frequencies > 1.2 Hz.

`2023_kilauea_3d_most_possibly_useable_horizontal_station_list_to_10Hz.csv`

This CSV file lists 722 3C stations that generally have good horizontal-component and H/V S/N for frequencies between 0.25 Hz and 10 Hz. Some of these stations have good horizontal-component and H/V S/N to frequencies of 20 Hz. This list includes 112 stations with modest wind-speed-dependent horizontal-component and H/V S/N decreases at frequencies > 2 –3 Hz, and some EPIC SS spiked-node resonance noise extending to 8 Hz.

`2023_kilauea_3d_lower_horizontal_noise_station_list.csv`

This CSV file lists 610 3C stations that generally have good horizontal-component and H/V S/N for frequencies between 0.25 Hz and 10 Hz. Some of these stations have good horizontal-component and H/V S/N to frequencies of 25 Hz. This list includes 124 stations with slightly decreased horizontal-component and H/V S/N at frequencies of 2–10 Hz relative to the lowest-noise list below.

`2023_kilauea_3d_lowest_horizontal_noise_station_list.csv`

This CSV file lists 486 3C stations that have good horizontal-component and H/V S/N for frequencies between 0.25 Hz and 10 Hz. Some of these stations have good horizontal-component and H/V S/N to frequencies of 25 Hz. These stations are most likely to provide usable S-wave amplitude information for moment tensor and full-waveform analyses.

The CSV file below identifies 15 EPIC SS spiked nodes for which the horizontal-component geophones are mostly decoupled from horizontal ground motions across wind-speed conditions. Horizontal-amplitude information from these stations should be used with caution; nearby stations in one or more of the lists above often provide better coupling and S/N.

`2023_kilauea_3d_decoupled_epic_ss_node_list.csv`

Supplemental Tables

Node Type	Normalization Frequency (Hz)	H/V Renormalization Amplitude
GTI U3 2.0 Hz	0.20	1.25
EPIC SS 5 Hz	0.24	1.30
HVO SS 0.2 Hz	0.29	1.35

Table S1 Nodal H/V renormalization parameters.

Supplemental Figures

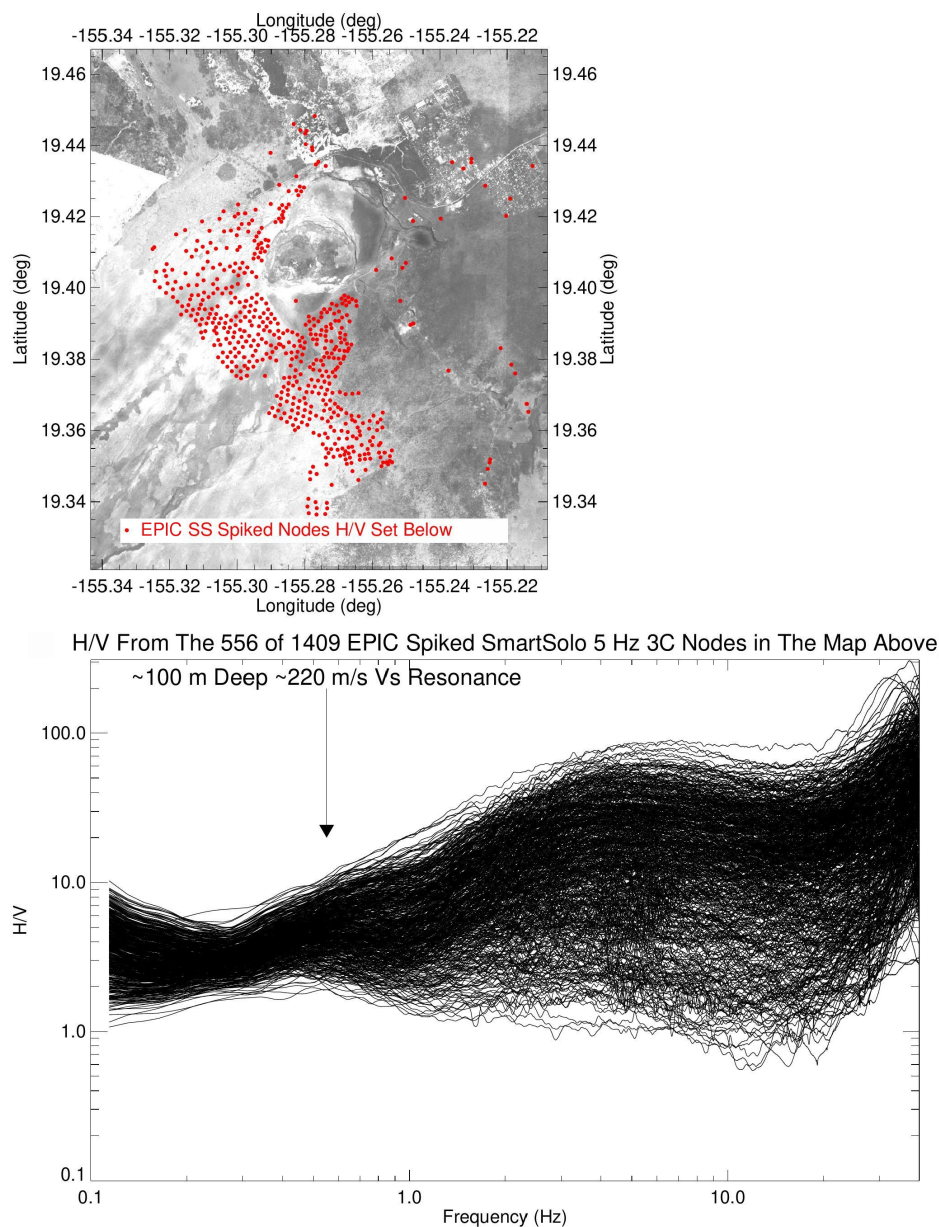


Figure S1 Top plot shows the locations of the 556 EPIC SS 5 Hz spiked 3C nodes. The bottom plot shows H/V curves for this subset of nodes, which have broadly similar H/V curve shapes. These nodes have the largest population of H/V curves with H/V at a frequency of 5 Hz ranging from 10 to 100 for most nodes and are located on volcanic tephra. These nodes do not have strong spike-resonance peaks. The most common H/V site-resonance peak observed for nodes located outside of Kīlauea caldera and other pit craters, at 0.55 Hz, is shown with the vertical arrow; this peak corresponds to a strong increase of S-wave velocity at a depth of 100 m from 220 m/s to 800–1200 m/s.

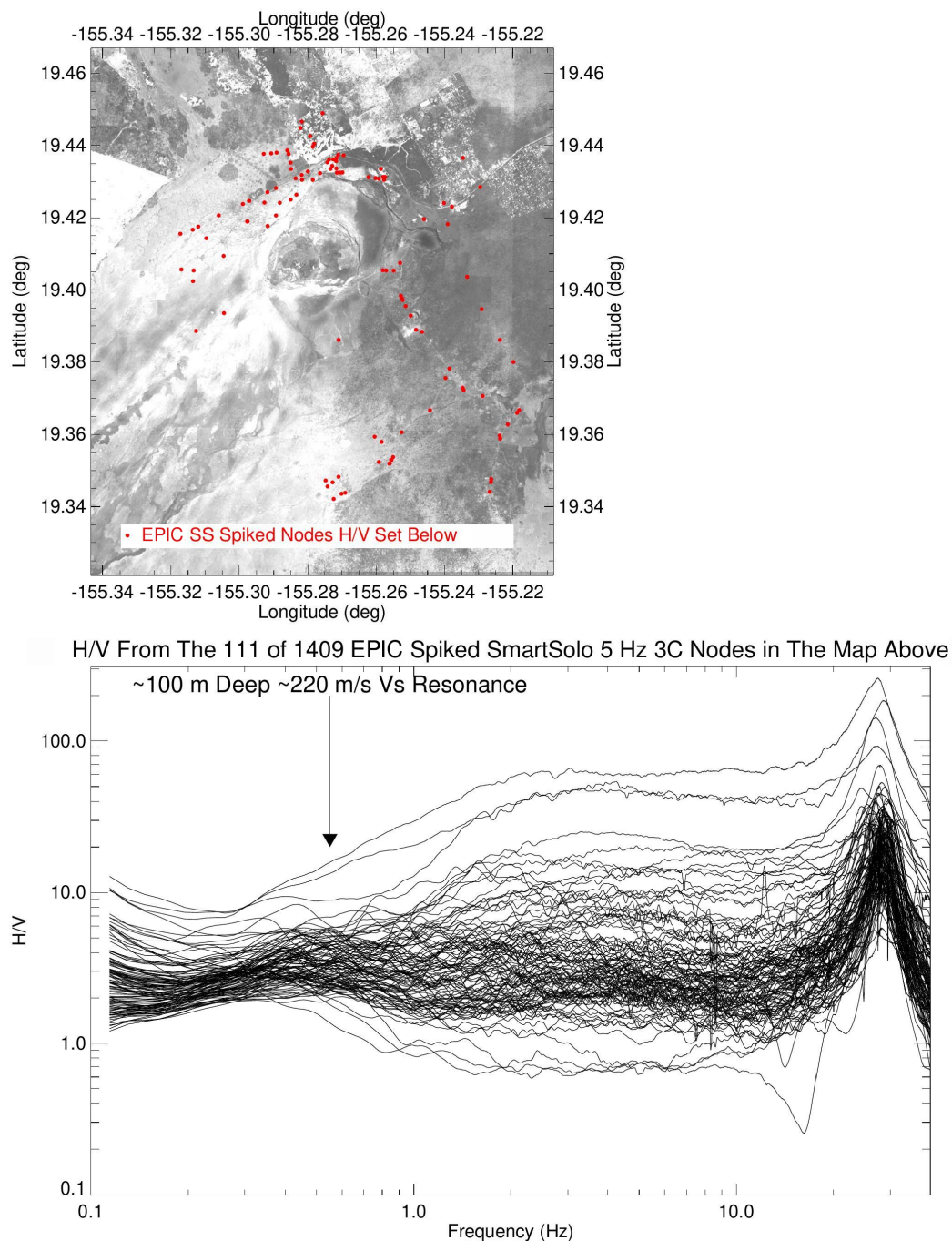


Figure S2 Top plot shows the locations of the 111 EPIC SS 5 Hz spiked 3C nodes with strong 28 Hz H/V spike-resonance responses shown in the bottom plot. The spike resonances generally do not extend below 10 Hz, and many of these H/V curves provide useful constraints on 0.2–10 Hz H/V site responses.

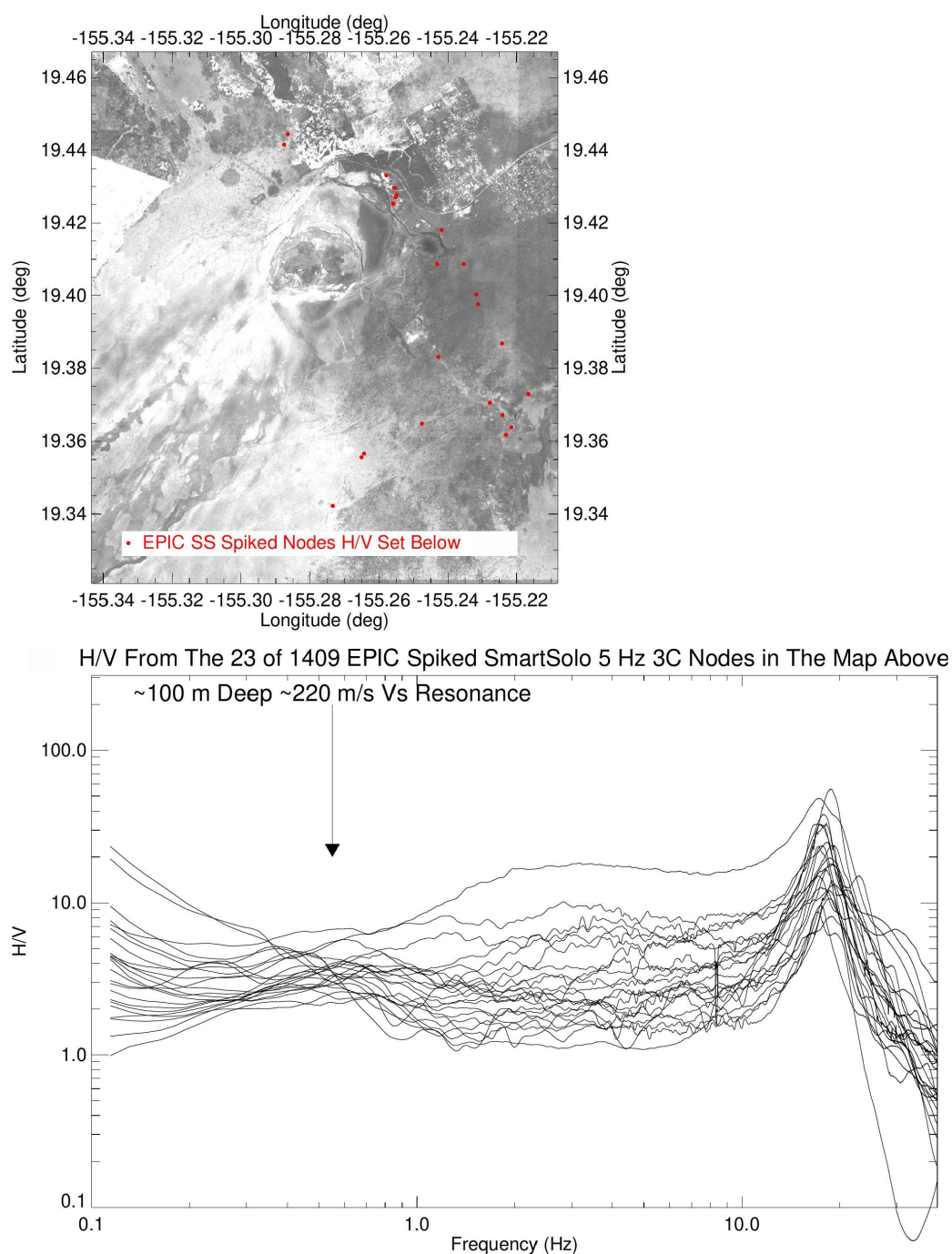


Figure S3 Top plot shows the locations of the 23 EPIC SS 5 Hz spiked 3C nodes with strong 18 Hz H/V spike-resonance responses shown in the bottom plot. The spike resonances often extend below 10 Hz. Some of these H/V curves provide useful constraints on 0.2–6 Hz H/V site responses, but several demonstrate near-zero ground coupling from 1–10 Hz combined with instability at frequencies below 0.5–1 Hz.

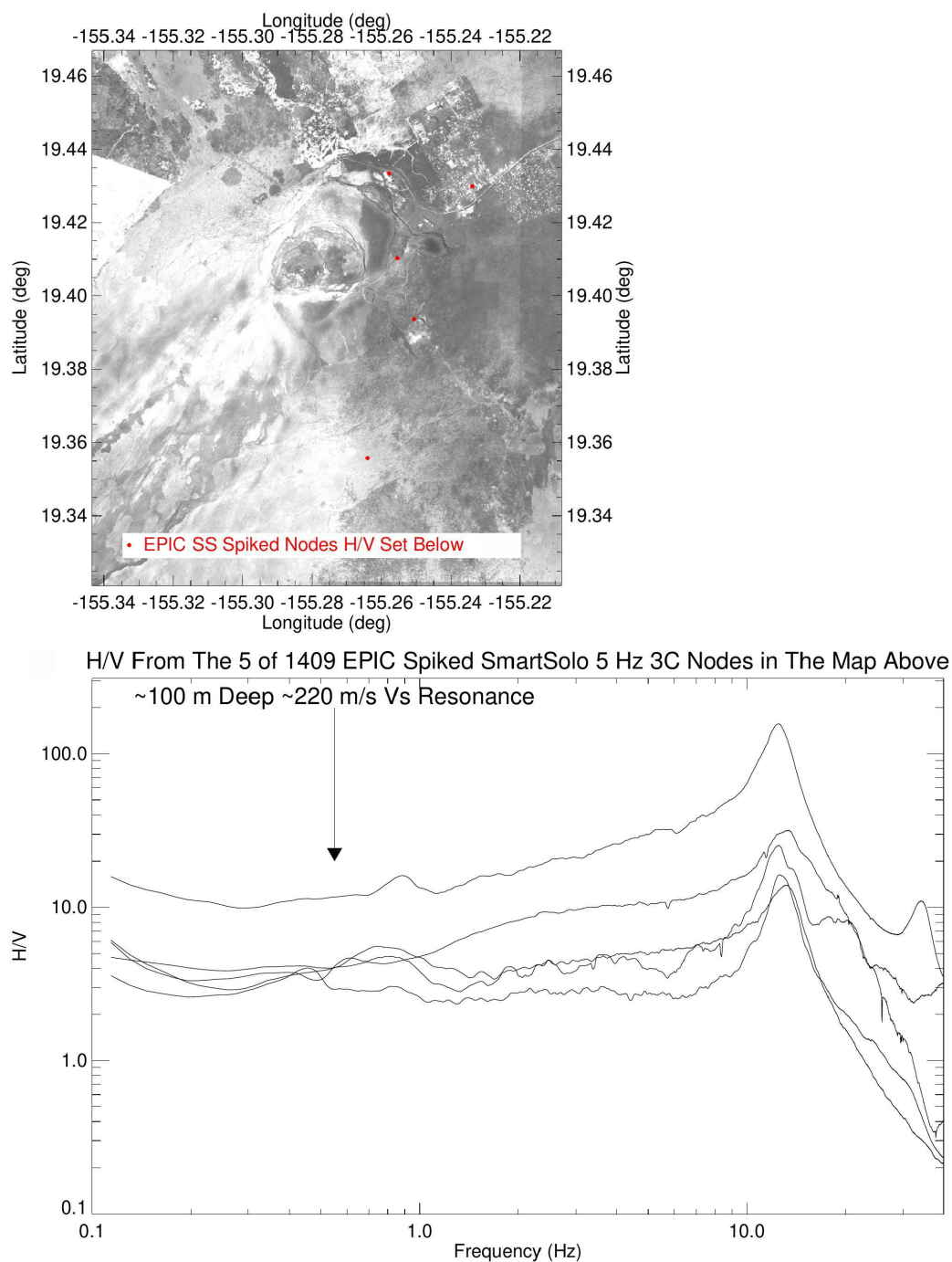


Figure S4 Top plot shows the locations of the five EPIC SS 5 Hz spiked 3C nodes with strong 12 Hz H/V spike-resonance responses shown in the bottom plot. These nodes show decoupling of horizontal ground motions at frequencies exceeding the spike-resonance frequency and spike-resonance noise extending down to 5 Hz. Two of these nodes show strong wind noise starting at frequencies > 1 Hz.

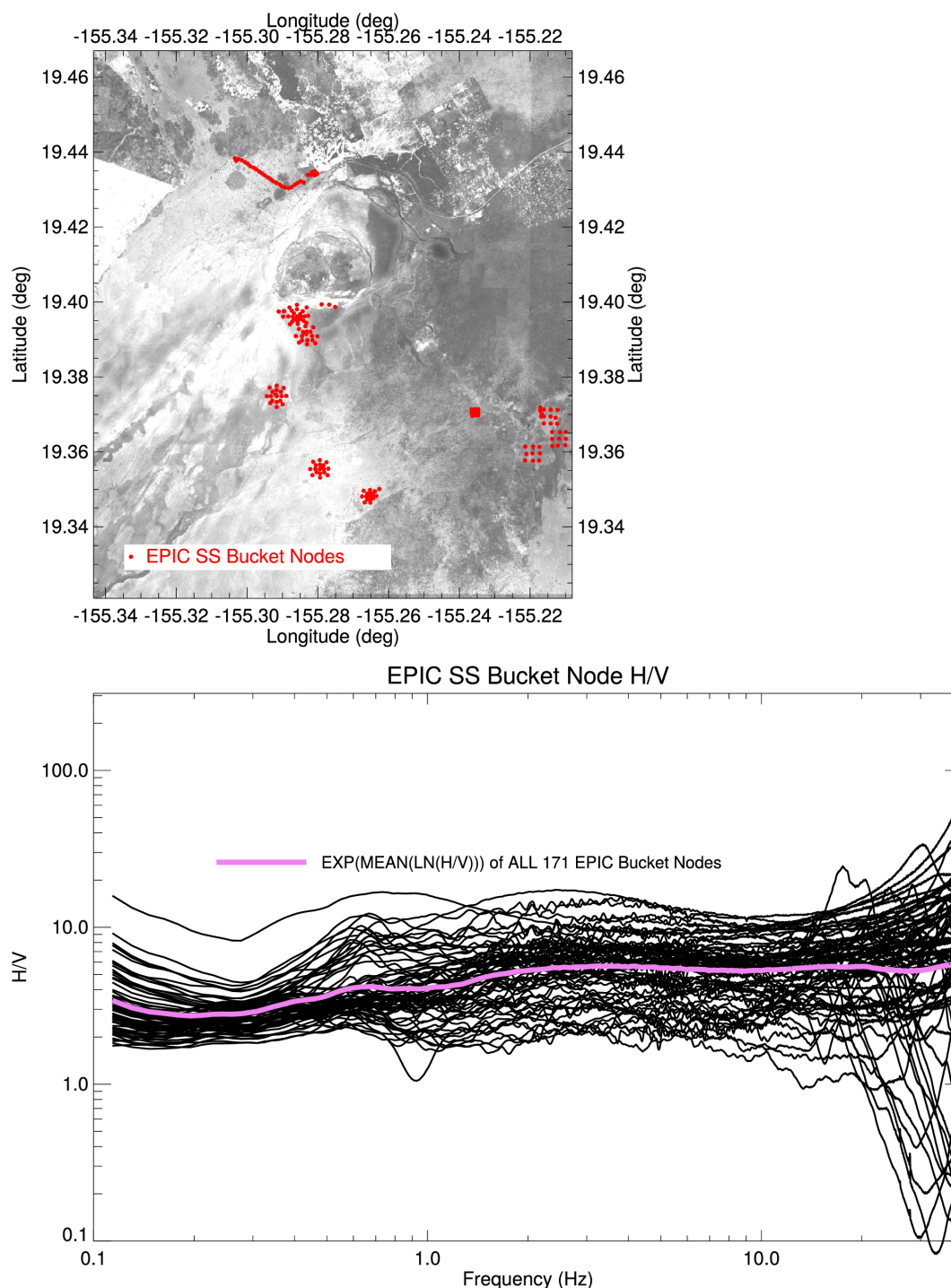


Figure S5 Top map shows the locations of all 171 EPIC SS 5 Hz bucket nodes. Their H/V curves do not exhibit the extreme H/V variability of the EPIC SS 5 Hz spiked nodes in Figures S1–S4 or in Figure 5. The EPIC SS 5 Hz bucket nodes do show a tendency toward persistent wind noise at frequencies > 1.2 Hz relative to the H/V curves from GTI U3 2 Hz nodes (Figure S6) and HVO SS 0.2 Hz nodes (Figure S7) as demonstrated in Supplemental Figures S8 and S9. The EPIC SS 5 Hz bucket nodes often show increasing horizontal-component noise at frequencies < 0.25 – 0.3 Hz.

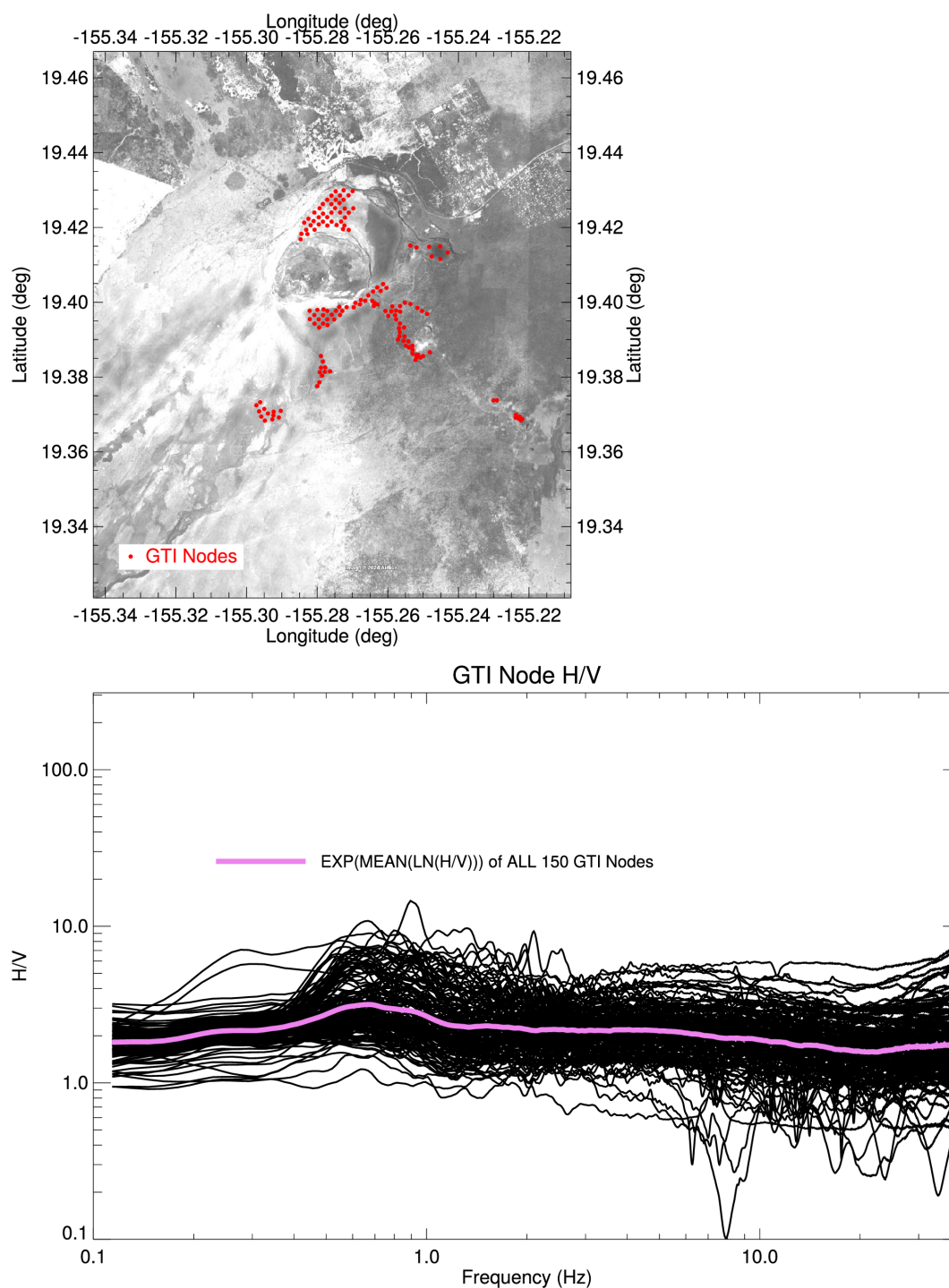


Figure S6 Top map shows the locations of all 150 3C GTI U3 2 Hz nodes. The largest H/V is an actual site topographic response (see Figure 8). These nodes show the least H/V variability of all node types (compare to Figures S1–S4, S5, and S7) and generally show H/V smoothly decreasing to 0.11 Hz (bottom plot).

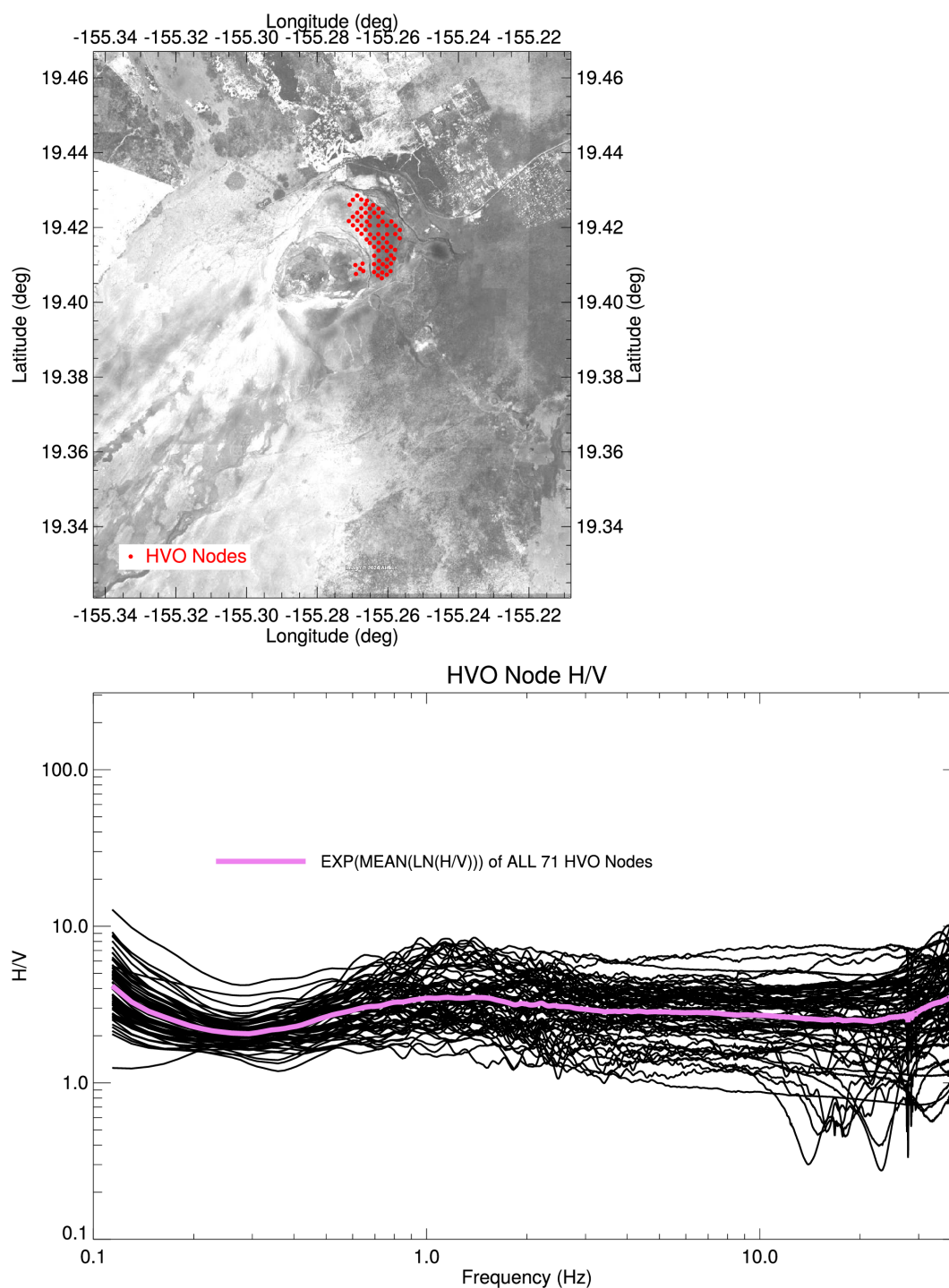


Figure S7 Top map shows the locations of all 71 3C HVO SS 0.2 Hz nodes. These nodes exhibit less H/V variability than the EPIC SS 5 Hz spiked and bucket nodes, except that H/V tends to increase from 0.3 Hz to 0.11 Hz (bottom plot).

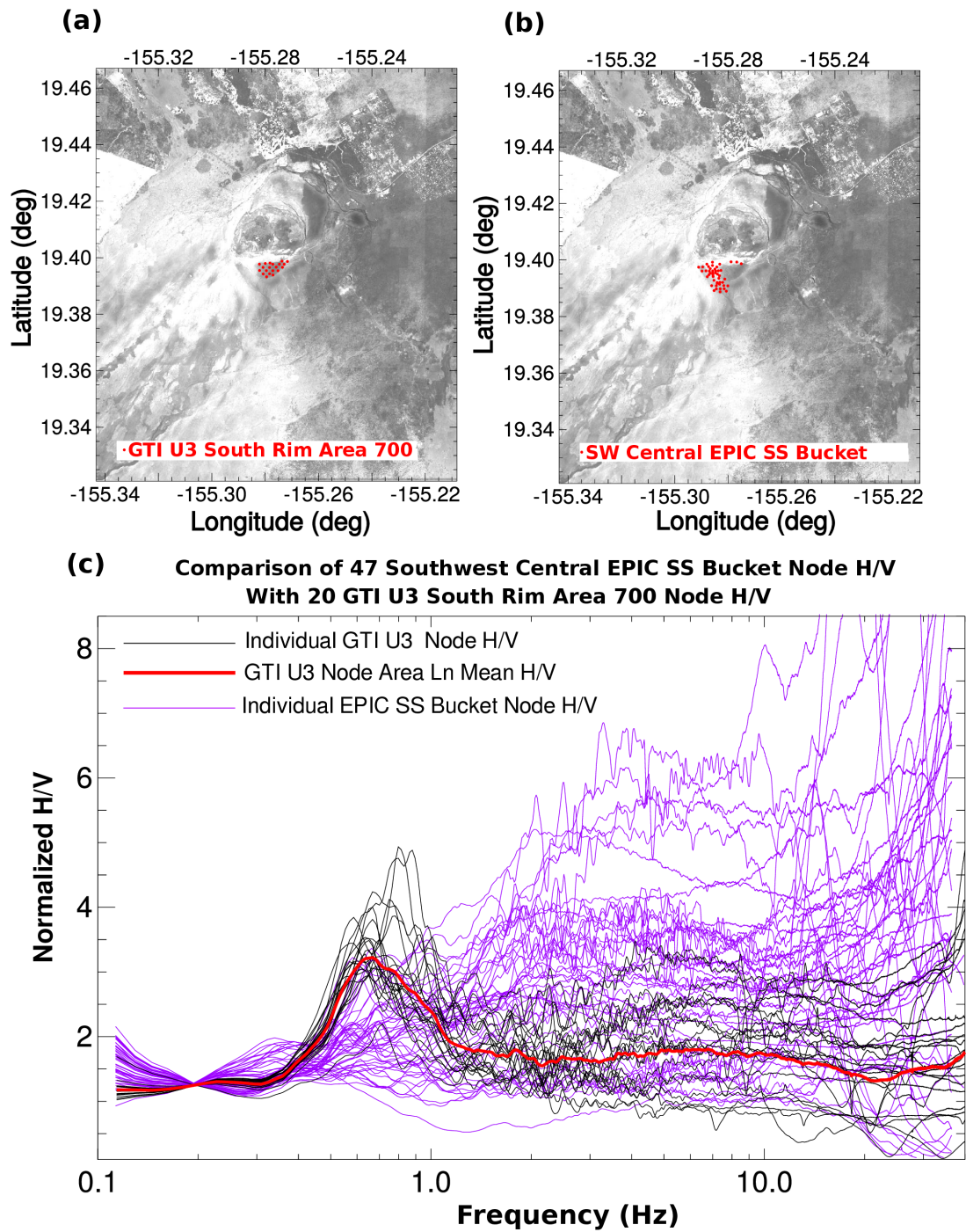


Figure S8 (a) Location of 20 GTI U3 South Rim Area 700 nodes on lava flows. (b) Location of 47 Southwest Central EPIC SS bucket nodes on lava flows. (c) Individual all hour GTI U3 node normalized $\ln$ mean H/V (thin black curves) and individual all hour EPIC SS bucket node normalized $\ln$ mean H/V (thin purple curves), with $\ln$ mean curve of the 20 GTI U3 node area $\ln$ mean curves in red.

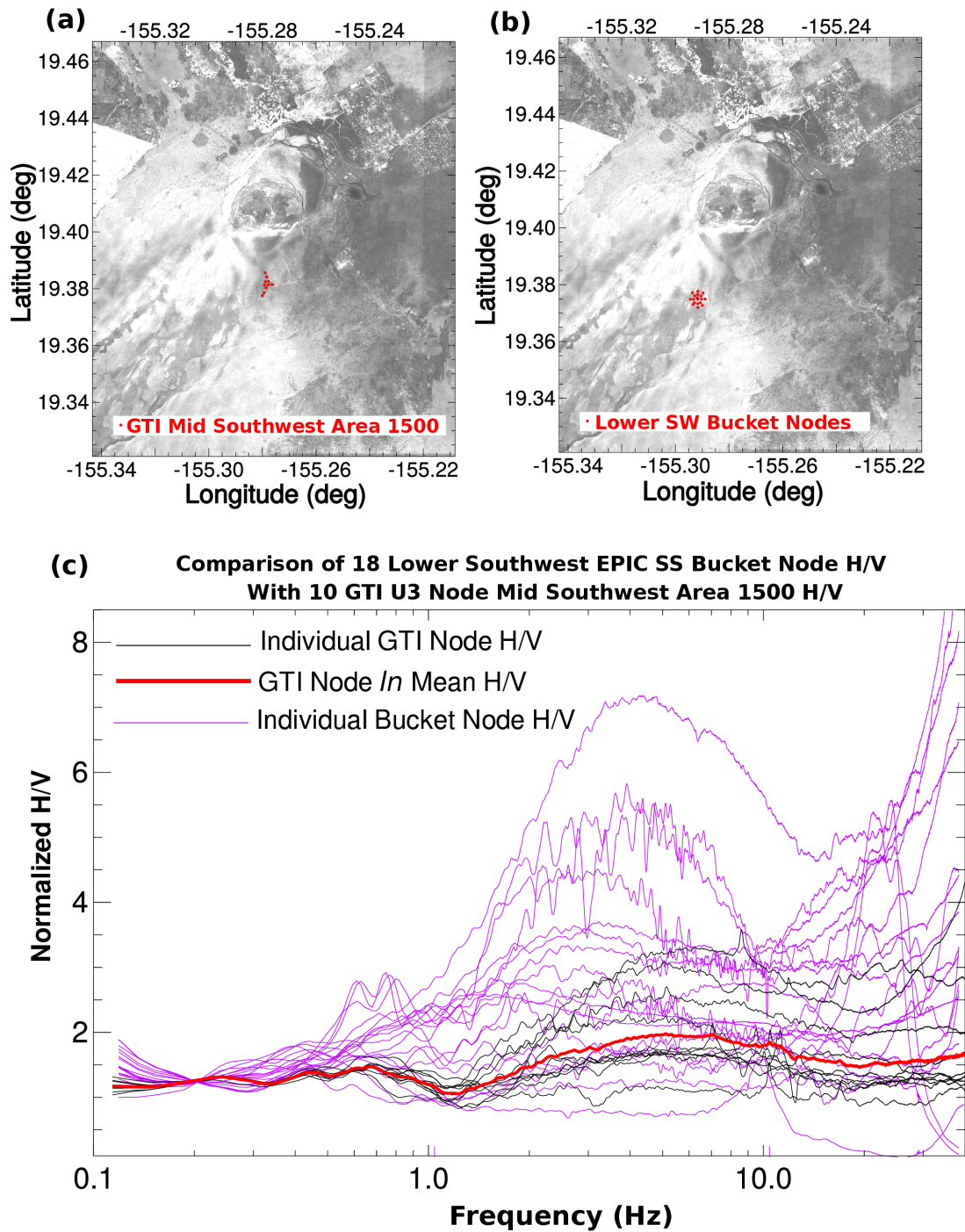


Figure S9 (a) Location of 10 GTI U3 Mid Southwest Area 1500 nodes on lava flows. (b) Location of 18 Lower Southwest EPIC SS bucket nodes on lava flows. (c) Individual all hour GTI U3 node normalized $\ln$ mean H/V (thin black curves) and individual all hour EPIC SS bucket node normalized $\ln$ mean H/V (thin purple curves), with the $\ln$ mean of the 10 GTI U3 node H/V curves in red.

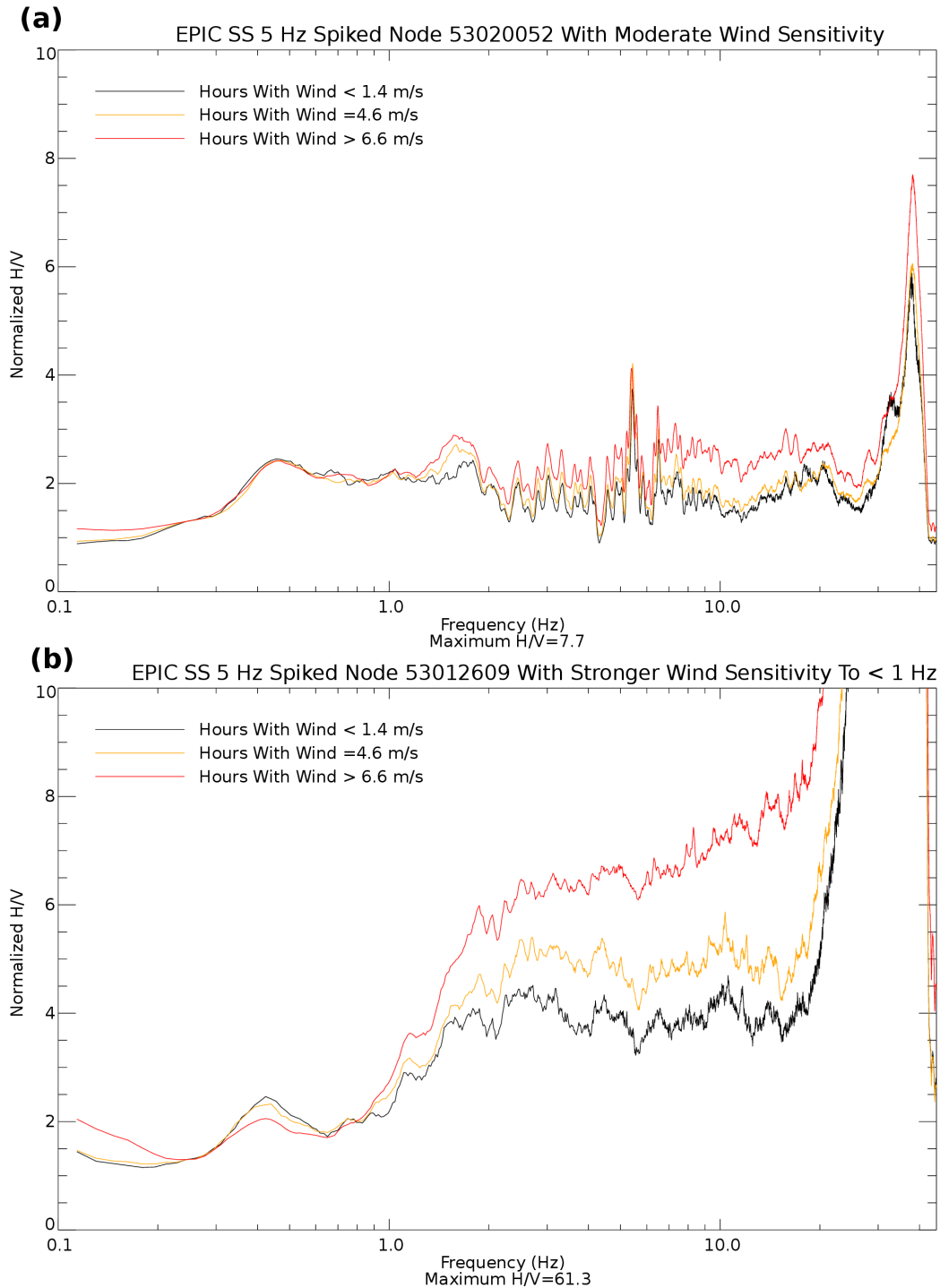


Figure S10 (a) This EPIC SS 5 Hz spiked 3C node has a 38 Hz spike-resonance frequency, with spike-resonance amplitude increasing when wind speed increases to 6.6 m/s or more. (b) The second EPIC SS 5 Hz spiked 3C node has much stronger H/V sensitivity to wind speed, with wind noise beginning to dominate H/V site-response signals at frequencies > 0.8 Hz and noise at frequencies < 0.25 Hz dominating for wind speeds exceeding 6.6 m/s. The H/V from (a) can still provide useful H/V and horizontal-component data for interferometry and lower-frequency site-response analyses, whereas the data from the node in (b) provide only limited constraints from 0.25 Hz to 0.8 Hz.

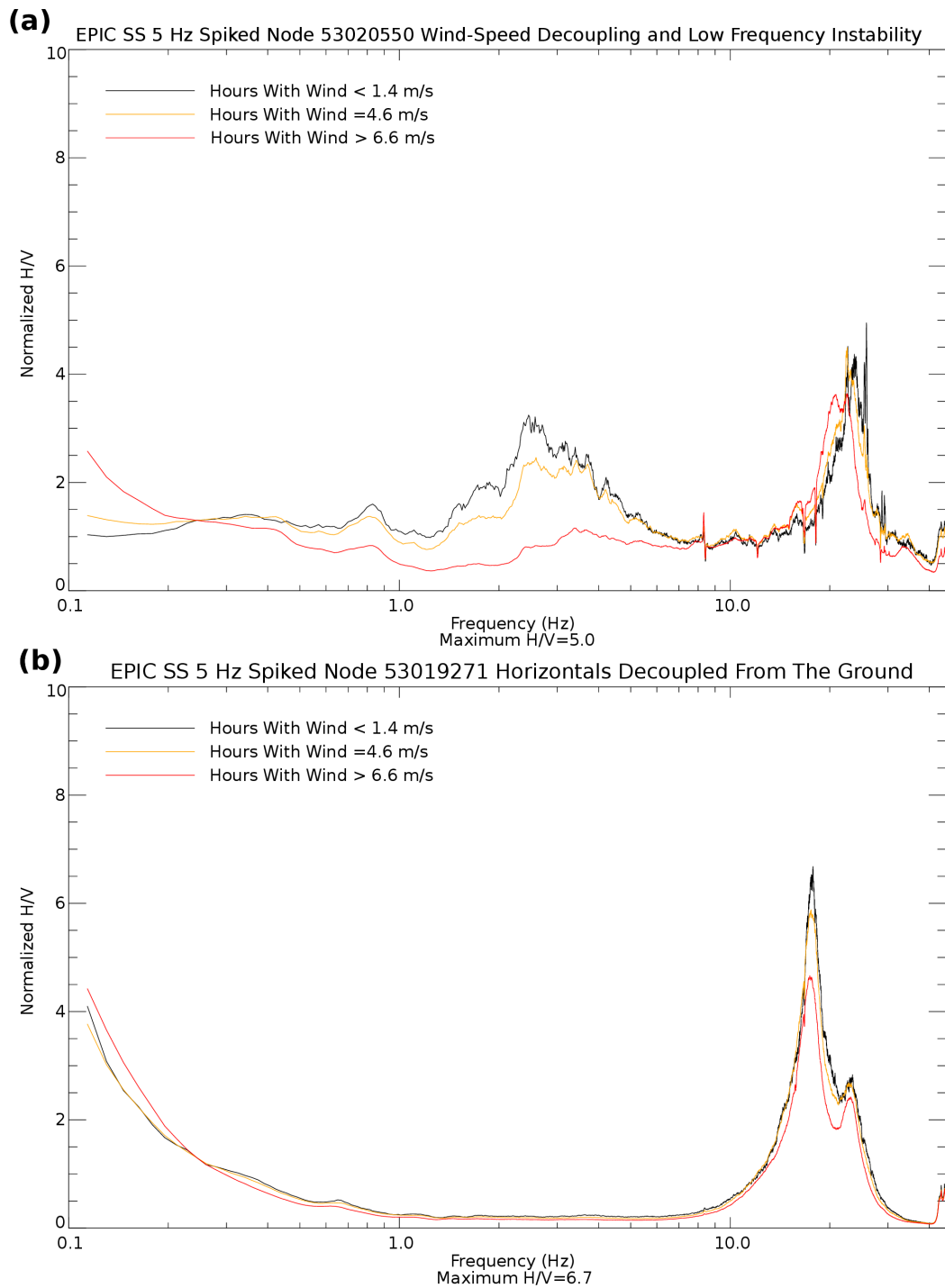
**Figure S-6.**

Figure S11 The EPIC SS 5 Hz spiked 3C node shows increasing horizontal ground decoupling with increasing wind speed, a lowering of the spike-resonance frequency at wind speeds exceeding 6.6 m/s, and increasing horizontal-component noise at frequencies < 0.25 Hz with increasing wind speed. (b) The EPIC SS 5 Hz spiked 3C node provides an example of nearly full horizontal-component ground decoupling of a spiked node in the 1 Hz to 10 Hz frequency band, with decreasing spike-resonance coupling with increasing wind speed, and increasing noise with decreasing frequency below 1 Hz.

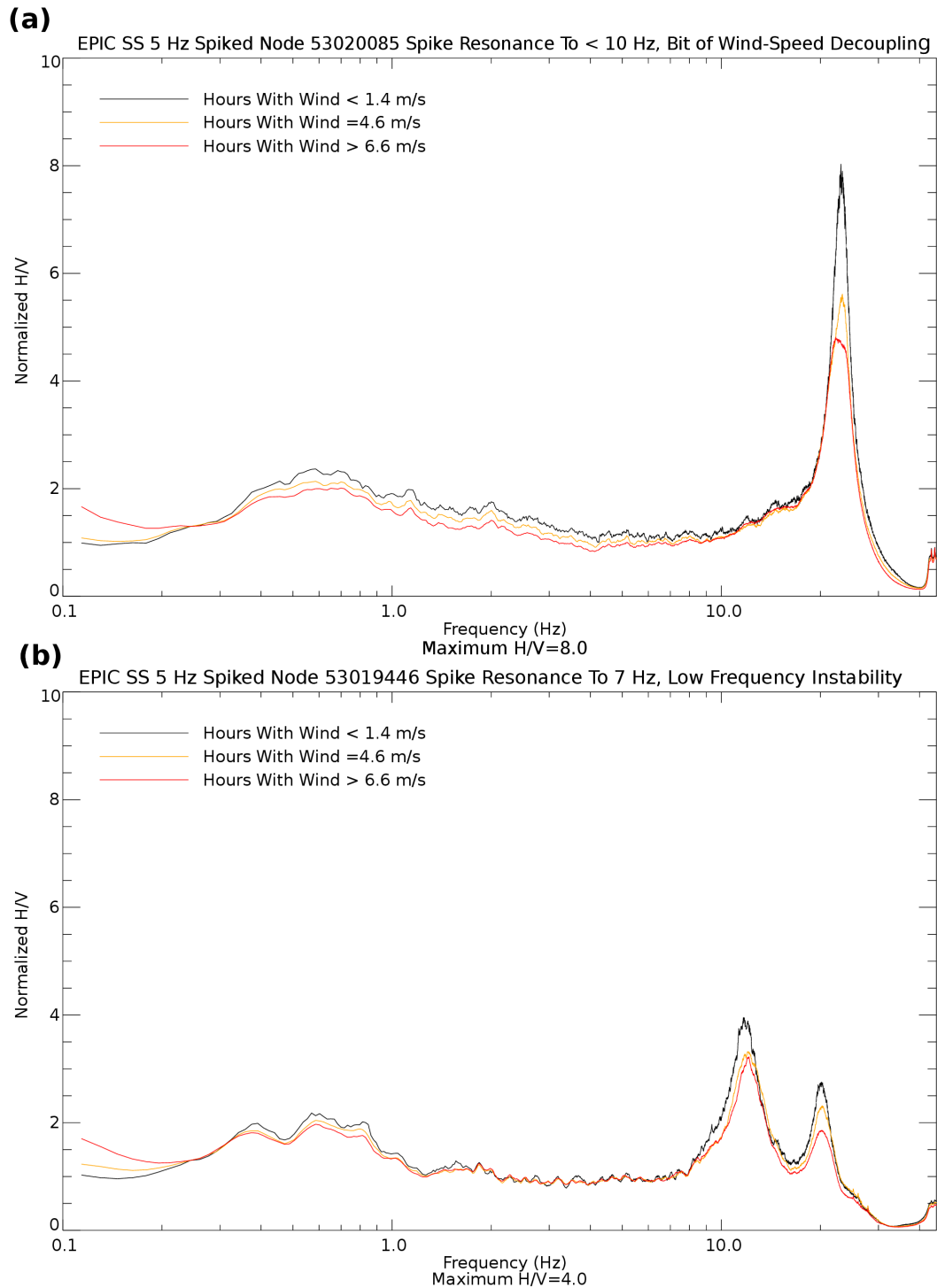


Figure S12 The EPIC SS 5 Hz spiked 3C node provides an example of a spiked node providing relatively wind-insensitive H/V and horizontal-component data in the 0.25 Hz to 10 Hz frequency band. Some wind noise and/or spike-resonant noise extends slightly below 10 Hz, but overall this node provides an example of a node rated as good quality to provide H/V and horizontal data for detecting and picking S-wave arrivals. (b) The EPIC SS 5 Hz spiked 3C node illustrates the conundrum produced by spike resonance: is the spike resonance the H/V peak at 20 Hz or at 12 Hz? This node provides unambiguously useful H/V data from 0.25 Hz to 8 Hz and may still provide sufficient horizontal-component S/N to successfully detect and pick S-wave arrivals.

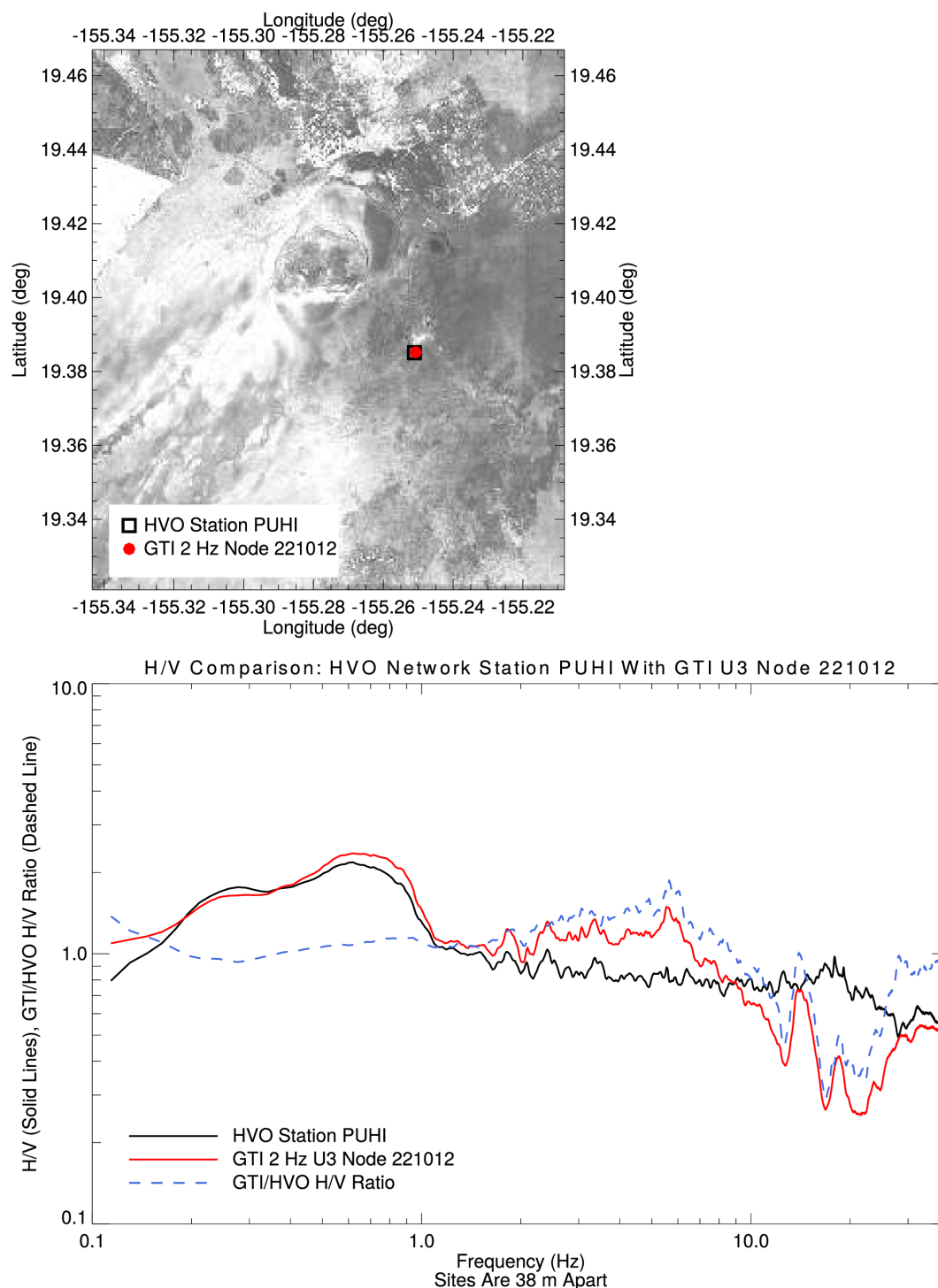


Figure S13 The top map shows the location of HVO network station PUHI in relation to the closest GTI U3 node 221012, with the two stations separated by 38 m and both installed in the southern portion of the 1967 ‘a’ā lava flow. The increase in GTI U3 221012 from 1.5 Hz to 6 Hz is probably a result of wind impacts on this node, which was placed on a platy lava surface that often had shallow voids beneath the surface; this may explain the low H/V response at frequencies > 8 Hz in the bottom plot. The HVO network PUHI station was placed in a posthole about 1.5 m deep.

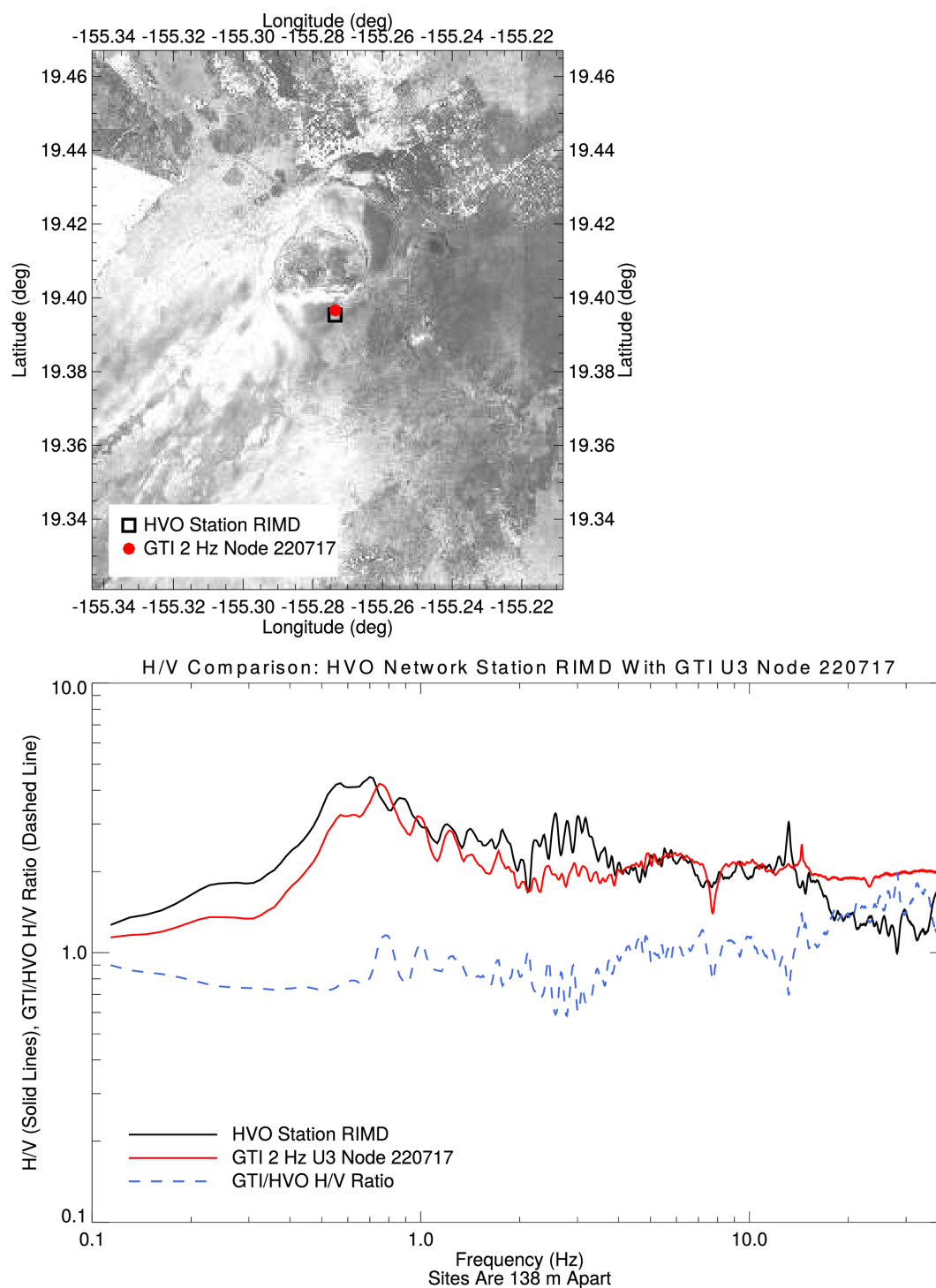


Figure S14 The top map shows the location of HVO network station RIMD, located 49 m from the closest GTI U3 node 220717. The HVO network station is installed in a posthole about 1.5 m deep; the GTI node was installed on volcanic tephra and is dominated by wind noise at frequencies > 1 Hz.

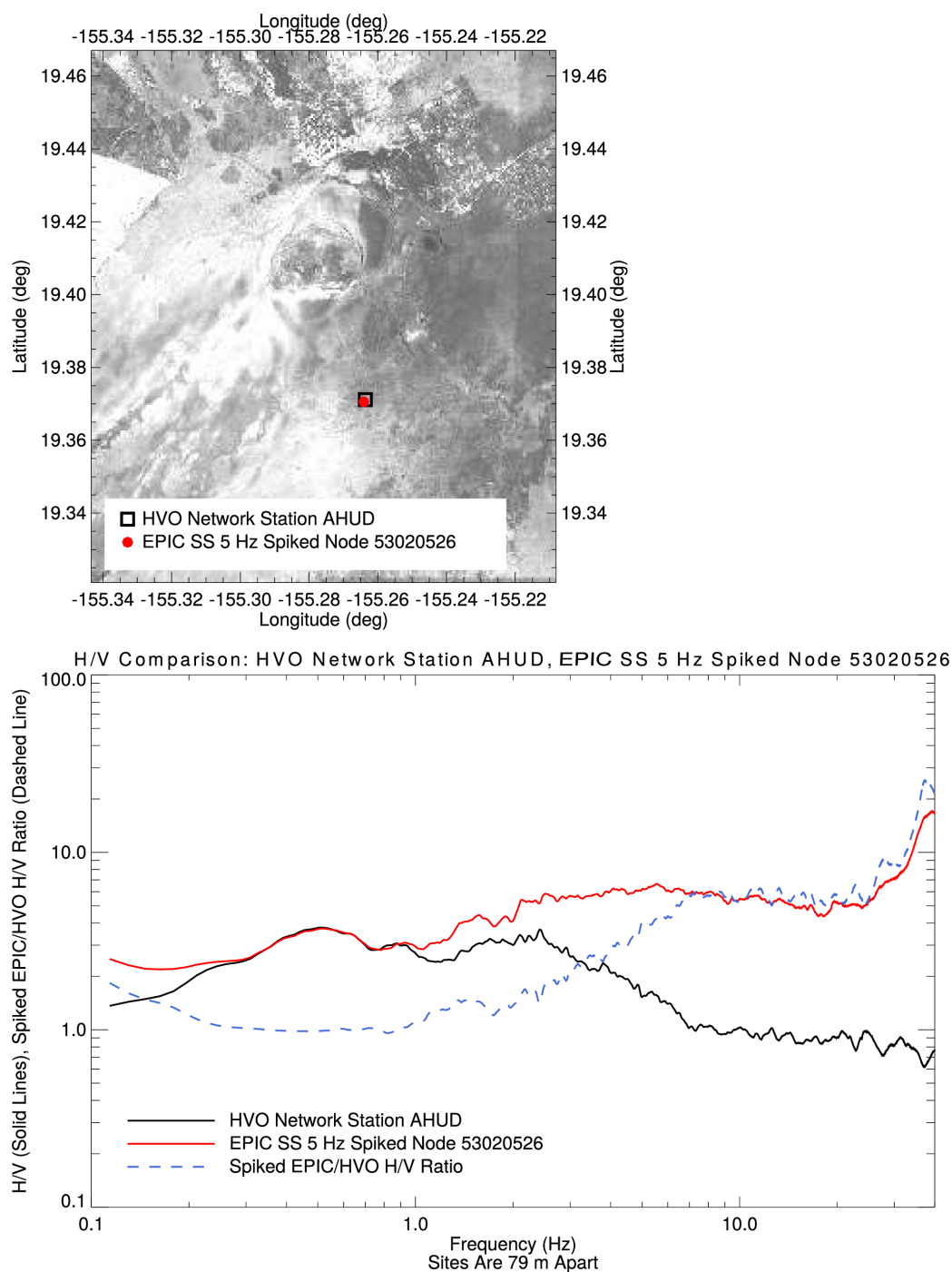


Figure S15 The top map shows the location of HVO network station AHUD located 79 m from the closest EPIC SS 5 Hz spiked node 53020526. Both stations have similar H/V responses from 0.3 Hz to 1 Hz, with wind noise dominating the EPIC SS 5 Hz spiked node 53020526 H/V with increasing frequency above 1 Hz. There is a spike resonance around 40 Hz .

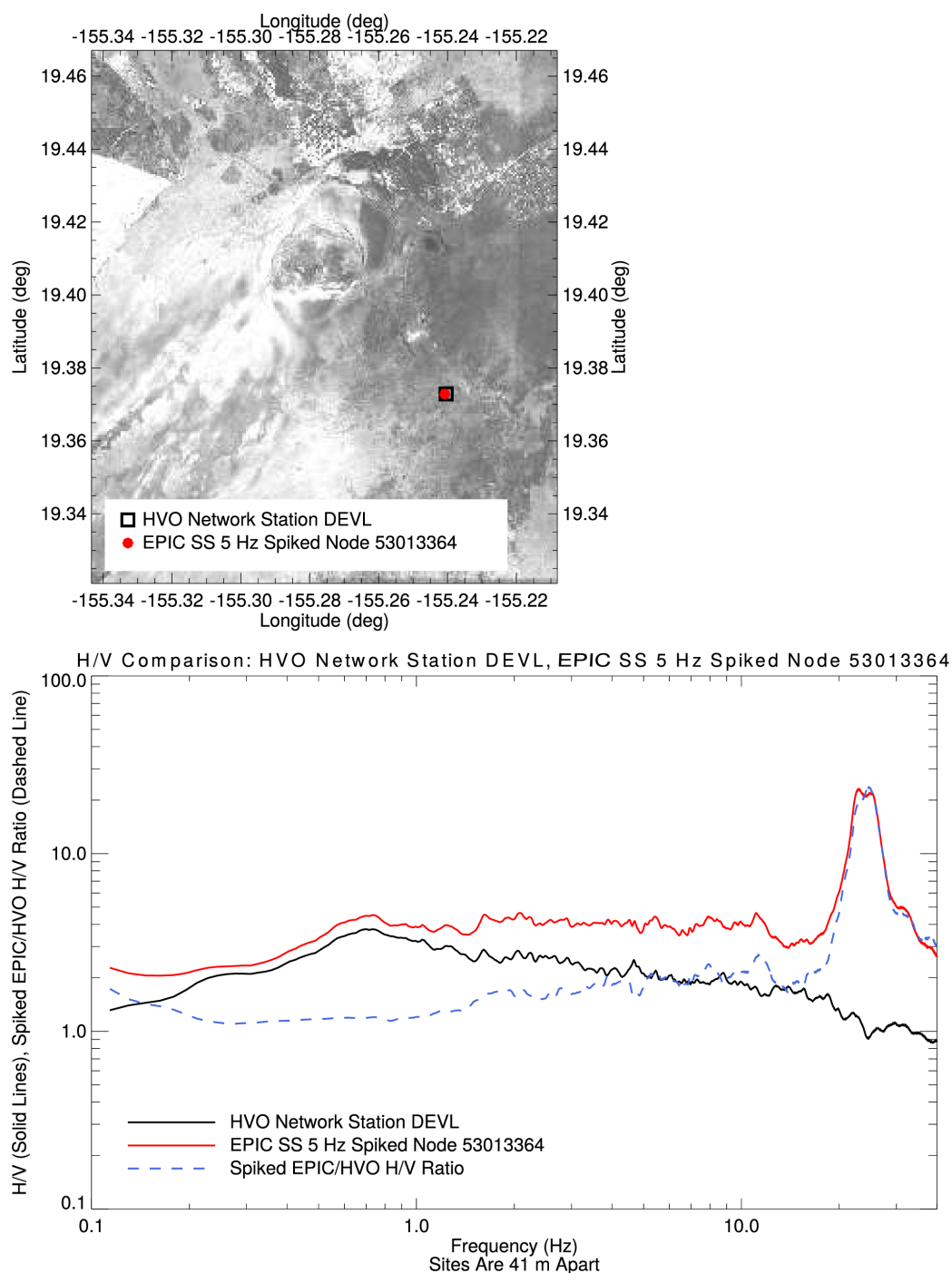


Figure S16 The top map shows the location of HVO network station DEVL located 41 m from the closest EPIC SS 5 Hz spiked node 53013364 spiked into soil. They have similar H/V responses from 0.25 Hz to 3 Hz, with the EPIC SS 5 Hz spiked node's H/V shifting upward with increasing frequency for frequencies > 1 Hz, culminating in a large spike resonance in the 22-24 Hz frequency range. This is an example of a EPIC SS 5 Hz spiked node with relatively modest wind sensitivity and a spike resonance that does not extend below 15 Hz, making it a node that may provide good S-wave data relative to noisier nodes.

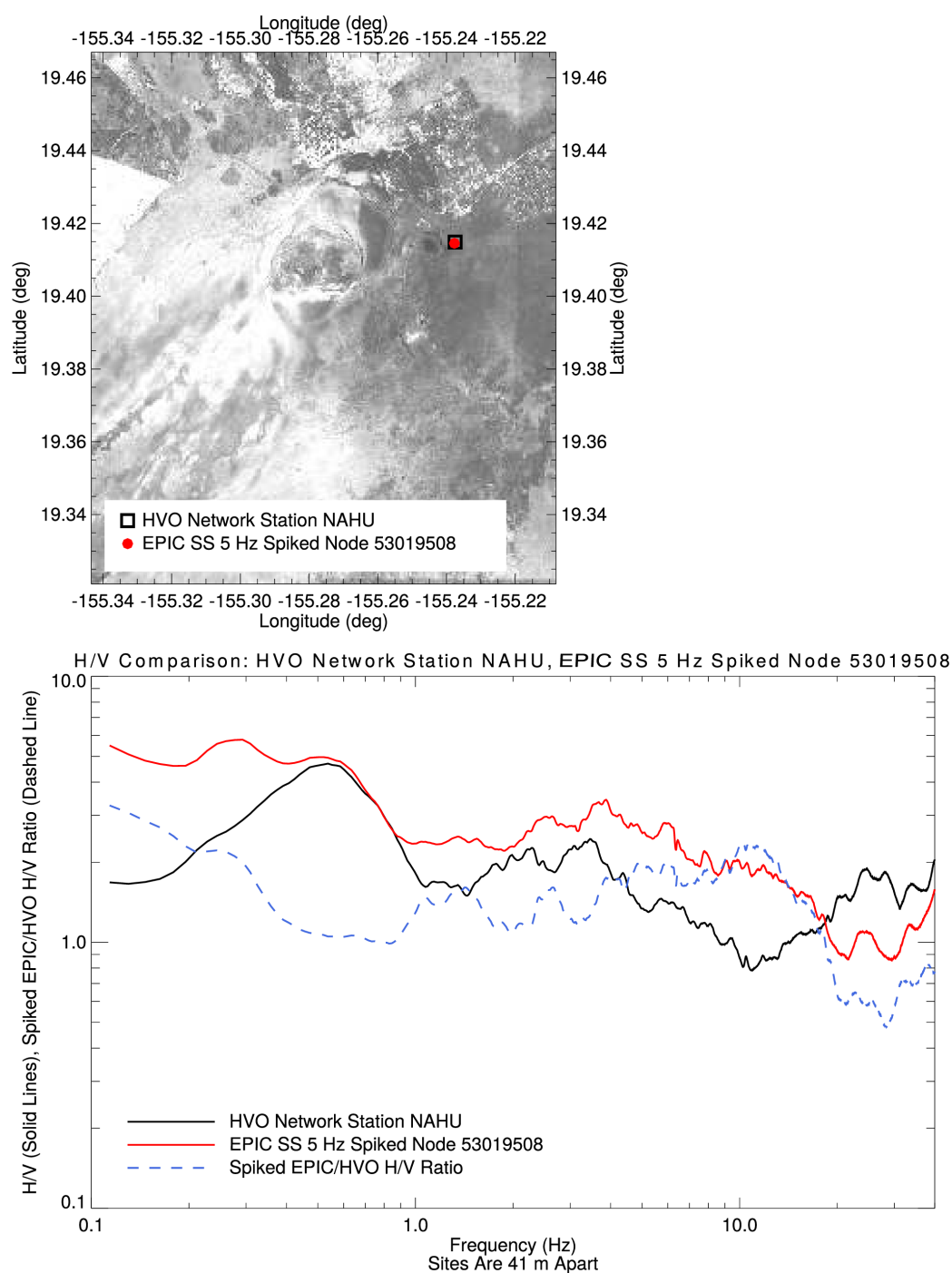


Figure S17 The top map shows the location of HVO network station NAHU located 41 m from the closest EPIC SS 5 Hz spiked node 53019508 into dense clay soil. This is another EPIC SS 5 Hz spiked node that is not strongly impacted by wind noise in the 0.5 Hz to 40 Hz frequency band, making it a good node station to search for S-wave arrivals although low-frequency jungle noise (rocking trees) increase horizontal noise for frequencies < 0.5 Hz.

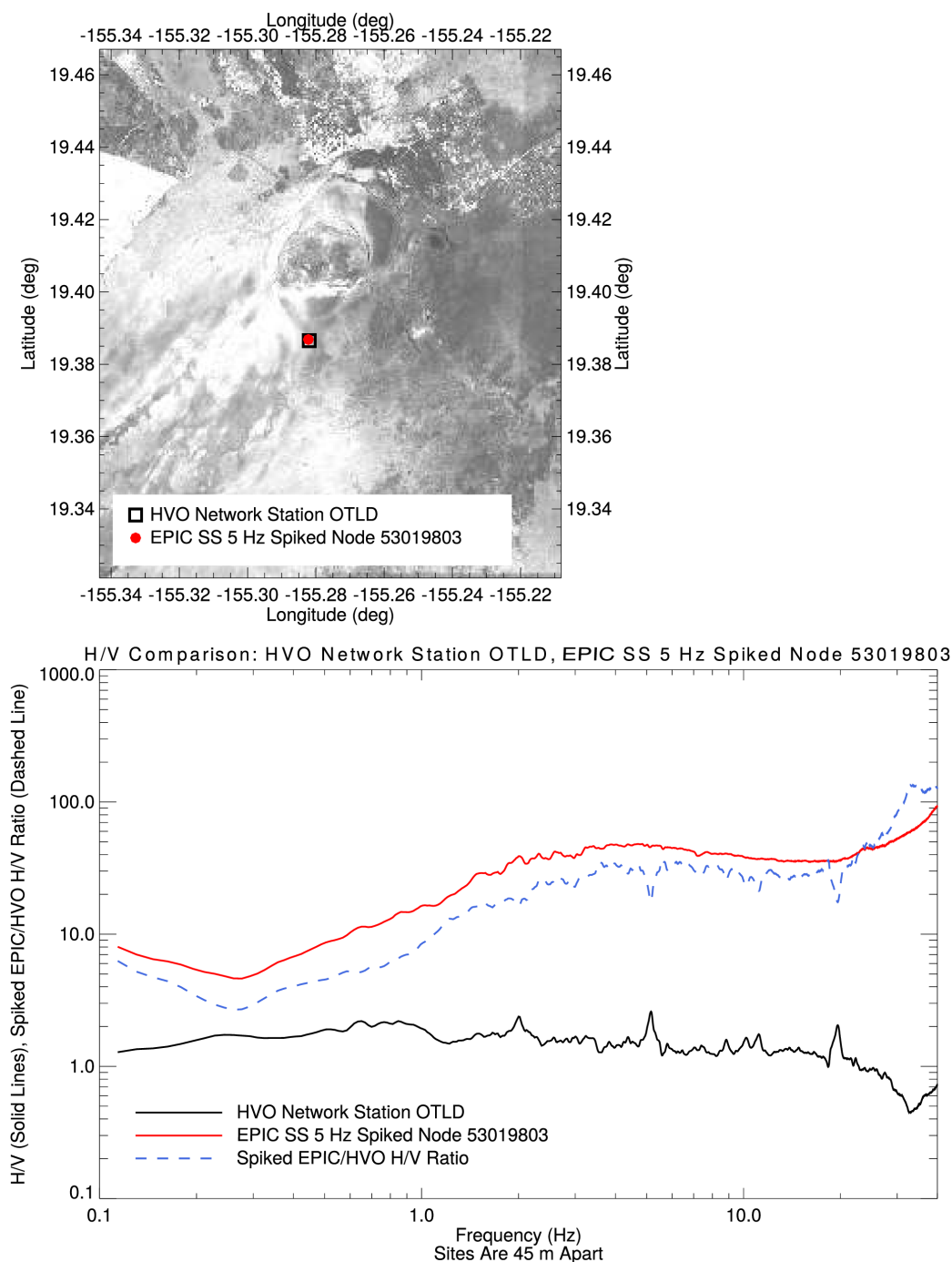


Figure S18 The top map shows the location of HVO network station OTLD located 45 m from the closest EPIC SS 5 Hz spiked node 53019803 spiked into volcanic tephra. This is an example of a EPIC SS 5 Hz spiked node that is dominated by wind noise at all frequencies.

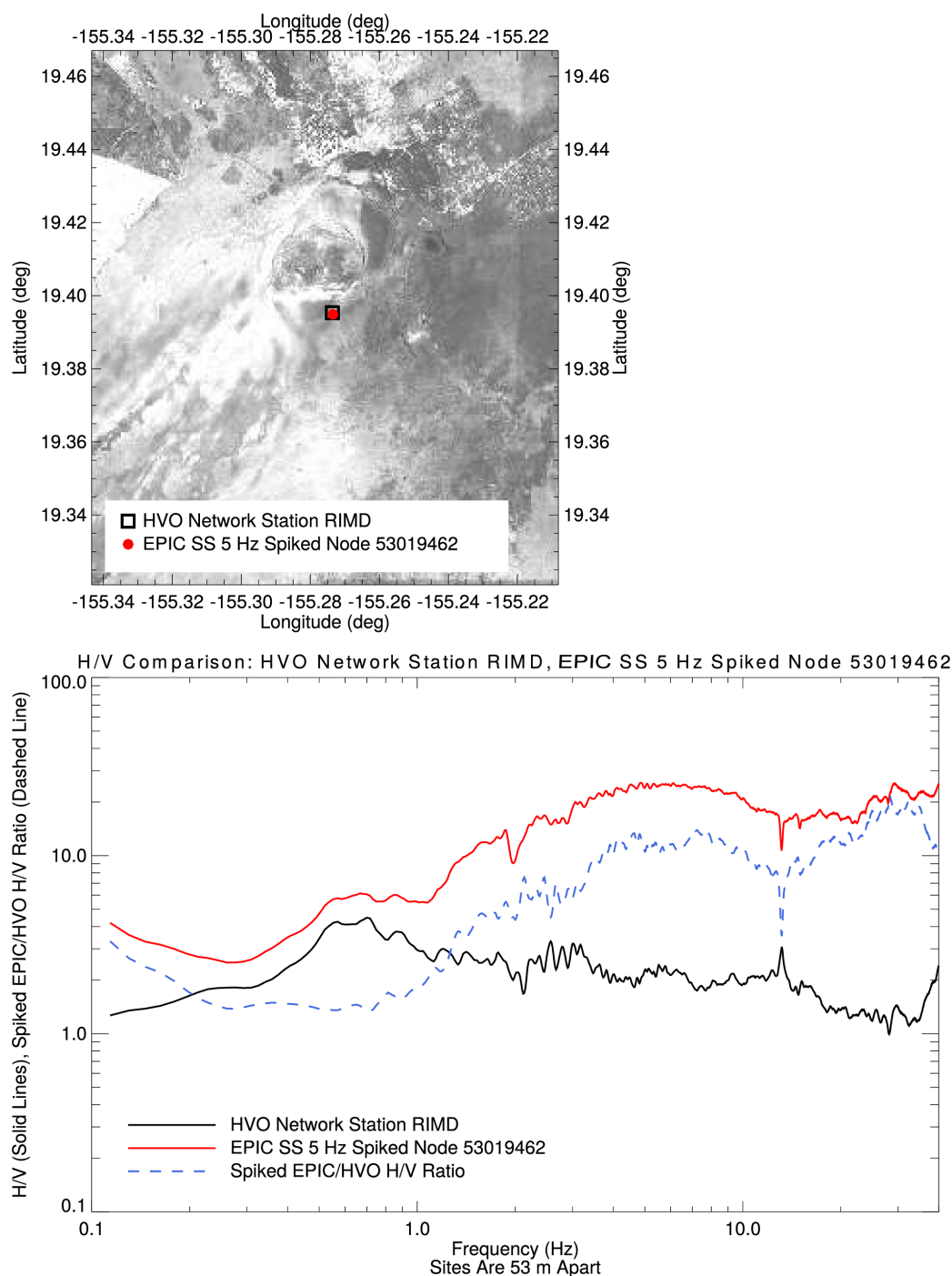


Figure S19 The top map shows the location of HVO network station RIMD in relation to the closest EPIC SS 5 Hz spiked node 53019462 installed in volcanic tephra, with the two station separated by 53 m. In contrast to the closest GTI U3 node in Fig. S14, the EPIC SS 5 Hz spiked node 53019462 shows strong wind noise dominating H/V at frequencies > 1 Hz. Both stations have similar detailed H/V shapes from 0.3 Hz to 3 Hz, but wind noise amplification of EPIC SS 5 Hz spiked node 53019462 eliminates qualitative H/V constraints at frequencies > 1 Hz and reduces horizontal-component S/N.

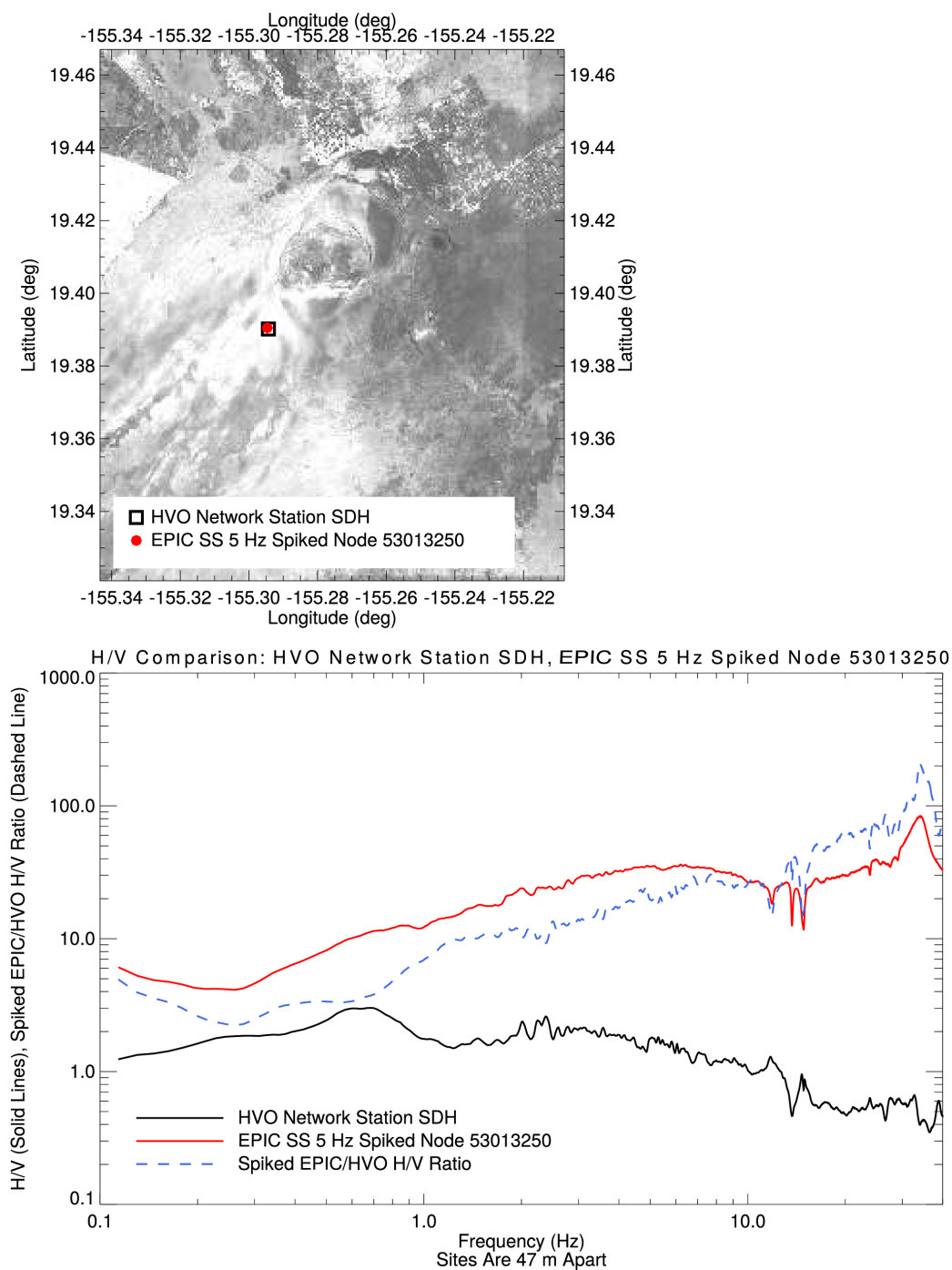


Figure S20 The top map shows the location of HVO network station SDH located 47 m from the closest EPIC SS 5 Hz spiked node 53013250 spiked into volcanic tephra. This is an example of a EPIC SS 5 Hz spiked node that is dominated by wind noise at all frequencies with a spike resonance at about 35 Hz.

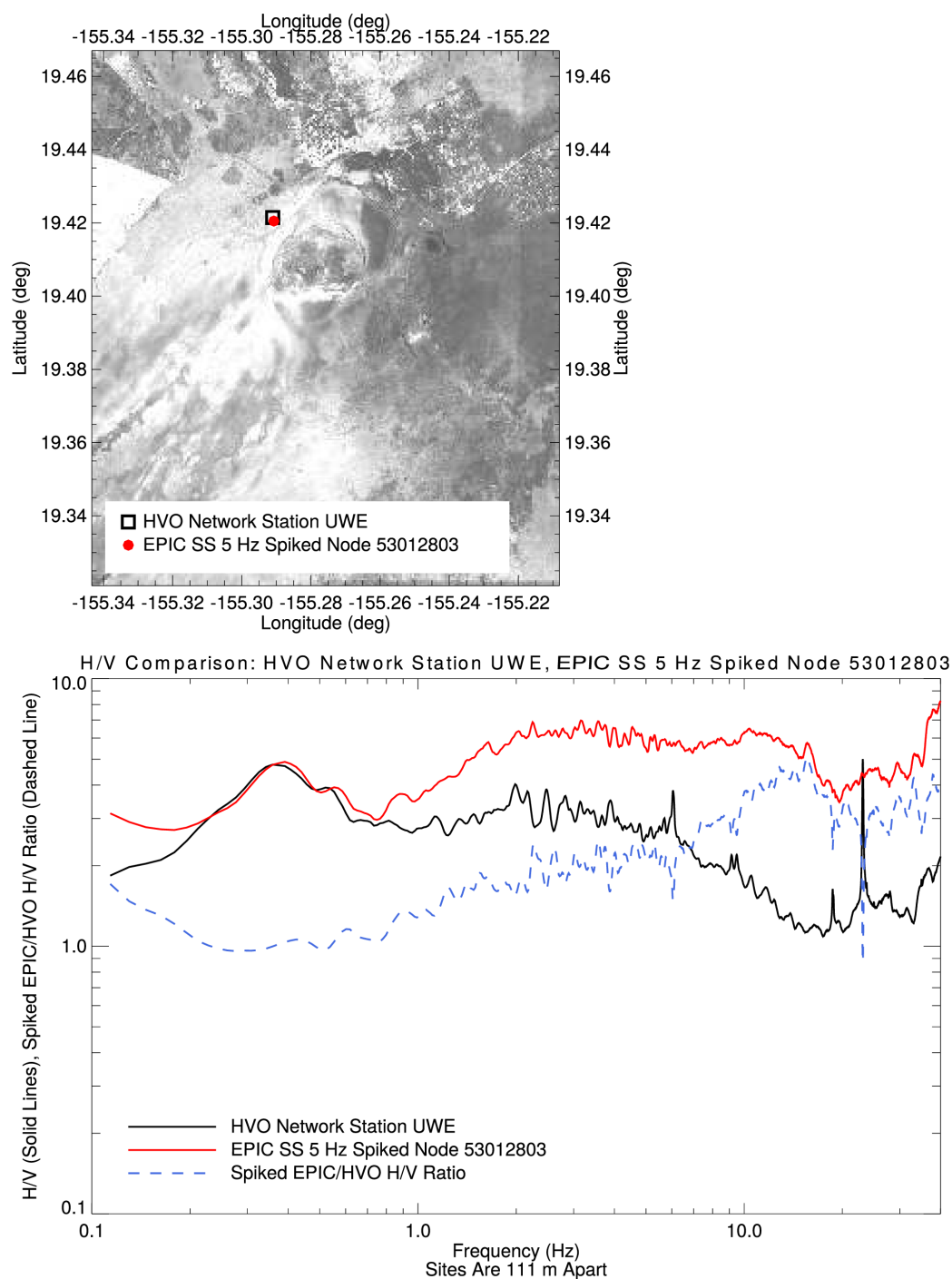


Figure S21 The top map shows the location of HVO network station UWE, located on a concrete pedestal in an underground room, 111 m from the closest EPIC SS 5 Hz spiked node 53012803. H/V is very similar from 0.25 Hz to 0.8 Hz; above 0.8 Hz, wind noise amplifies the H/V from the EPIC SS 5 Hz spiked node 53012803.

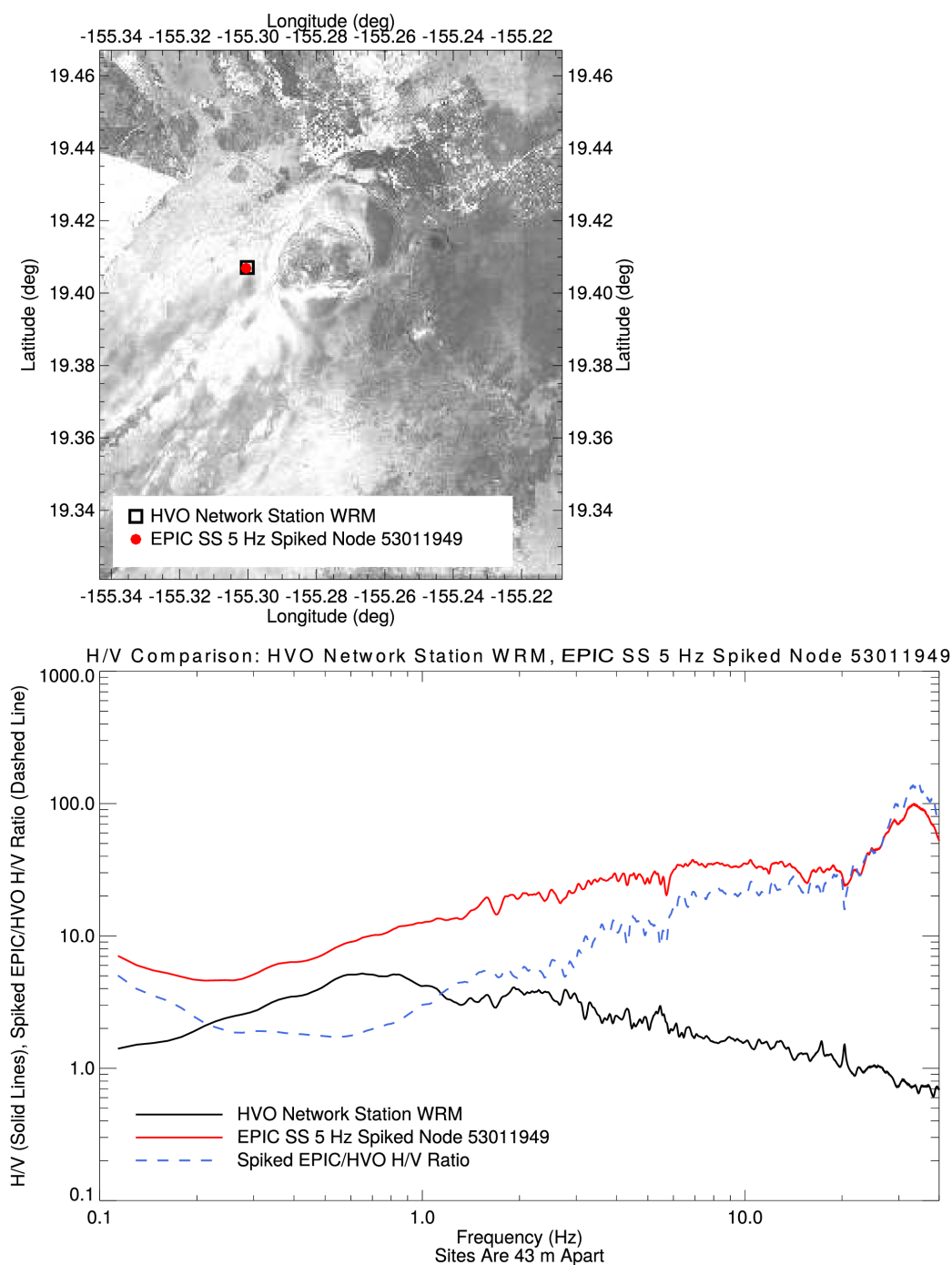


Figure S22 The top map shows the location of HVO network station WRM, located 43 m from the closest EPIC SS 5 Hz spiked node 53011949 spiked into volcanic tephra. This is another example of a EPIC SS 5 Hz spiked node that is dominated by wind noise at all frequencies, with a spike resonance at about 35 Hz.

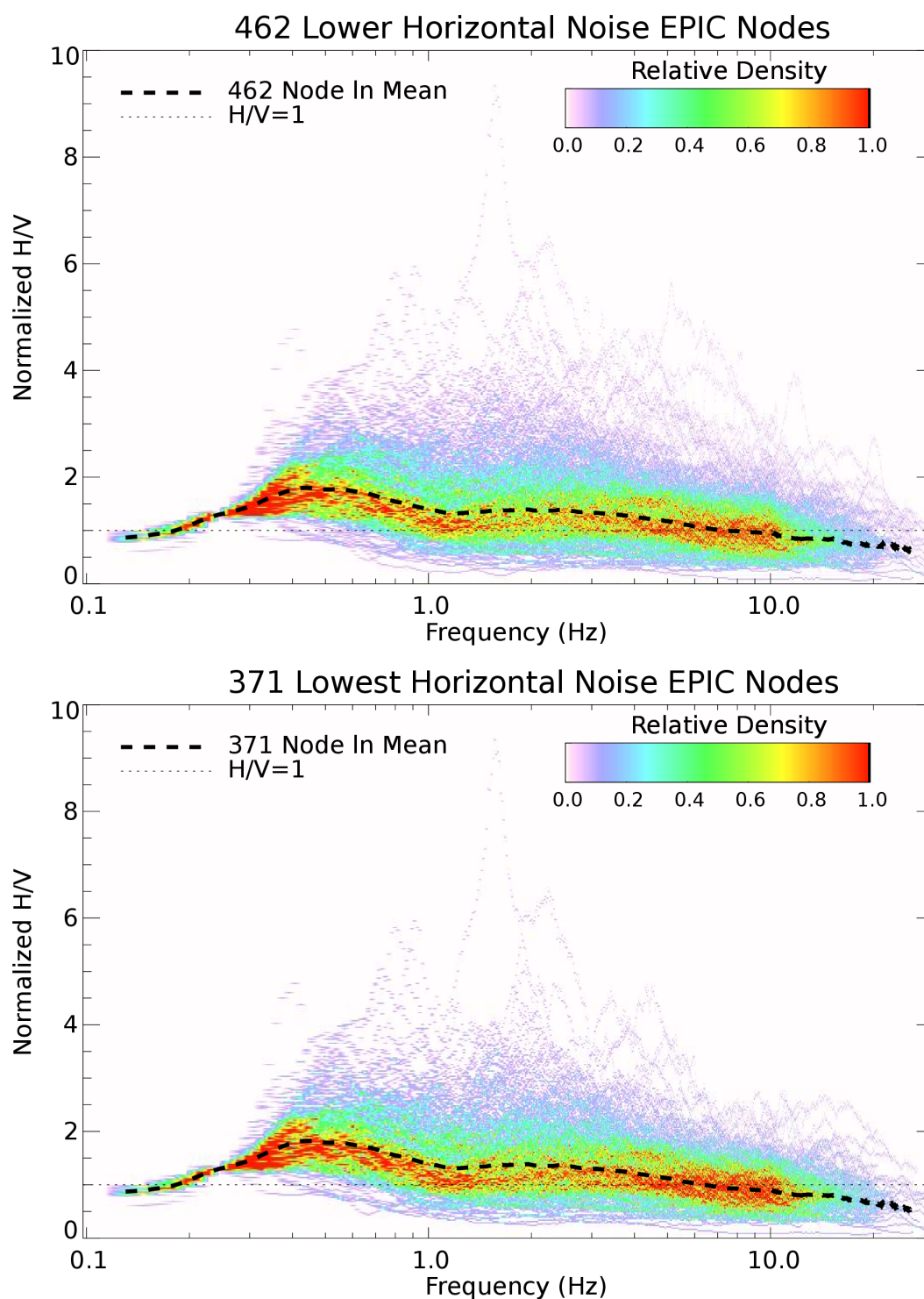


Figure S23 H/V relative density of the 462 EPIC SS nodes included in the lower horizontal noise station list (top) and H/V relative density of the 371 EPIC SS nodes included in the lowest horizontal noise station list (bottom). These relative densities demonstrate the absence of nodes with strong spike resonances impacting H/V at frequencies < 10 Hz.