DYNAMIC STABILITY MONTHLY REPORT

NORTH ISLAND – AUGUST 2024

Transpower New Zealand Limited

August 2024

Keeping the energy flowing

Transpower New Zealand Limited The National Grid

Version	Date	Change
1.0	21/07/2025	Final

	Position	Date
Prepared By:	Power Systems Engineer	9/06/2025
Reviewed By:	Richard Sherry, Principal Engineer	21/07/2025

Contents

1 Executive summary

1.1 Purpose

The low frequency dynamic oscillatory stability of the power system has been analyzed using phasor measurement unit data.

These monthly reports can be used to track significant changes over time specifically aimed at documenting 'normal' system oscillation behaviour and identifying any changes.

If some oscillation modes have changed significantly, or there is evidence of poor damping events, a more detailed investigation would be required to identify the cause (e.g. load growth, new generation, machine or plant controller, system topology/outages, etc.)

The reporting for 2024 is modified to a more "by exception" approach. The normally observed oscillation behaviour for the Island is quite well known from a number of years of reporting. This is summarized in section 2.1. Any new or unusual behaviour observed in the month is then reported in section 2.2.

1.2 Revisions from January 2024

The report format has been updated for 2024. The histograms of recorded data are retained, but the previous time trends have been replaced with a new formatting of the data which also captures, in the time series trend, the behaviour of all identified oscillations across the frequency spectrum (of 0.04 to 4 Hz) rather than presenting just the largest mode within a number of specified frequency bands.

The new format contains more information, a summary of how to interpret the new plots has been included along with a comparison of how the pre-2024 trend would look.

2 Oscillation Behaviour

2.1 Typical Modes observed on the Island

Mode freq.	Signal	Comments	Typical Behaviour
0.04 Hz	All-f All-P	Low frequency hydro governor mode Well damped but detected almost continuously	Frequency analysis - at all sites Magnitude observed is in the 10 to 30 mHz range, decay time in the 10 to 40s range (which is only 1 or 2 cycles at this frequency) MW analysis – Magnitude is typically up to 2 or 3 MW but varies at different sites and can be up to 6 MW, decay time in the 10 to 40s range
0.25 Hz	All-f	Consistently observed but the cause has not been identified Can have periods of very low damping, but remains at low magnitude. Will be investigated if the magnitude increases	Frequency analysis - at all sites Magnitude observed is in the 1 to 5 mHz range, decay time can be up to 100s (or more) MW analysis – mode is detected with similar long decay times, but magnitude is very low, less than 1 MW
0.5–0.6 Hz	All-f	Not continuously observed, but very common. Very low magnitude Possibly an inter-area mode but not identified in linear analysis.	Frequency analysis - Magnitude up to 2 mHz, decay time typically 10 to 20s. MW analysis – Magnitudes below 1 MW at all sites, decay times similar to the frequency analysis
0.7–0.9 Hz	All-f All-P	Inter-area modes. Usually continuously observed but low magnitude	Frequency analysis - Magnitude up to 2 mHz, decay time typically below 10s but can be up to 20s. MW analysis – Magnitudes typically below 2 MW at all sites, decay times similar to the frequency analysis
0.95–1.4 Hz	All-f All-P	Local and inter-area modes. Commonly observed at all sites,	Frequency analysis - Magnitude up to 2 mHz, decay

		such modes exist for all synchronous generation	time typically 10s but can be up to 20s. MW analysis – Magnitudes up to 2 MW at all sites, decay times up to 40s.
1.6 Hz	All-f All-P	Inter-station modes for central NI generation Continuously observed	Frequency analysis - Magnitude up to 2 mHz, decay time typically 10s but can be up to 40s. MW analysis – Magnitudes up to 2 MW at all sites, decay times up to 100s at BPE.
1.8 Hz	BPE-f BPE-P	TNG load related (up to 5/8/2024). Observed at most sites at a lower magnitude than at BPE. Mode disappears after Winstone TNG factory closure	Frequency analysis - Magnitude (BPE) up to 5 mHz, decay time typically 20s but can be up to 100s. MW analysis – Magnitude (BPE) up to 6 MW, decay times similar to frequency.
>2.0 Hz	All-f	Controller modes Observed intermittently across all sites. Very low magnitude and well damped.	Frequency analysis - Magnitude rarely above 0.5 mHZ, decay time under 10s MW analysis – magnitude up to 1 MW but usually below 0.5 MW, decay time under 10s.

2.2 Unusual Behaviour Observed this month

Nothing unusual to report.

The closure of the disturbing load at TNG is clearly visible on the reduction of 1.8Hz modes after 5th August.

Note: the HLY PMU analysis shows a step change in the results after 22nd August 02:00 – data beyond this date is invalid due to an intermittent loss of time synchronization. The problem was resolved from 16:00 on 2nd September.

3 How To Interpret the Graphical data

The reporting is done in various plots, which are explained in this section.

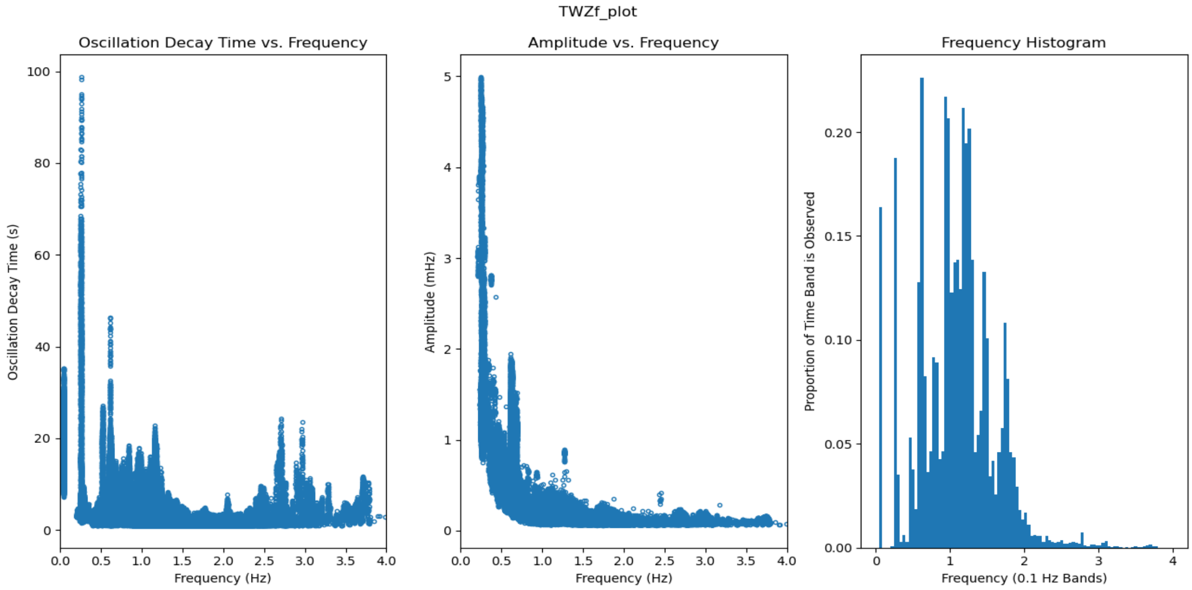
The analysis is done on two power system variables : frequency (Hz) and Real Power (MW)

At PMUs measuring reactive power devices only frequency is analyzed, but we have no PMUs like this in the North Island. So in the North Island reports there are 6 locations for both frequency and MW.

Section 4.1 has histogram plots. These show the decay time (1st plot) and magnitude (middle plot) of every recorded oscillation mode (the frequency of the mode is the x-axis in 0.1 Hz increments). These do not show when the particular points were recorded.

The 3rd plot is a cumulative frequency plot to indicate how often each particular modal frequency (in 0.1 Hz bands) was reported. The source software reports on the modes it detects, updated at 20 second intervals, and it can identify from 0 to 5 modes at each time. For a 31 day month there would be 133,920 results (= 3*60*24*31) with 0 to 5 modes in each – and the histogram is showing the proportion of the 133,920 results which contained this mode frequency.

Example below is the (South Island) TWZ frequency analysis histograms :

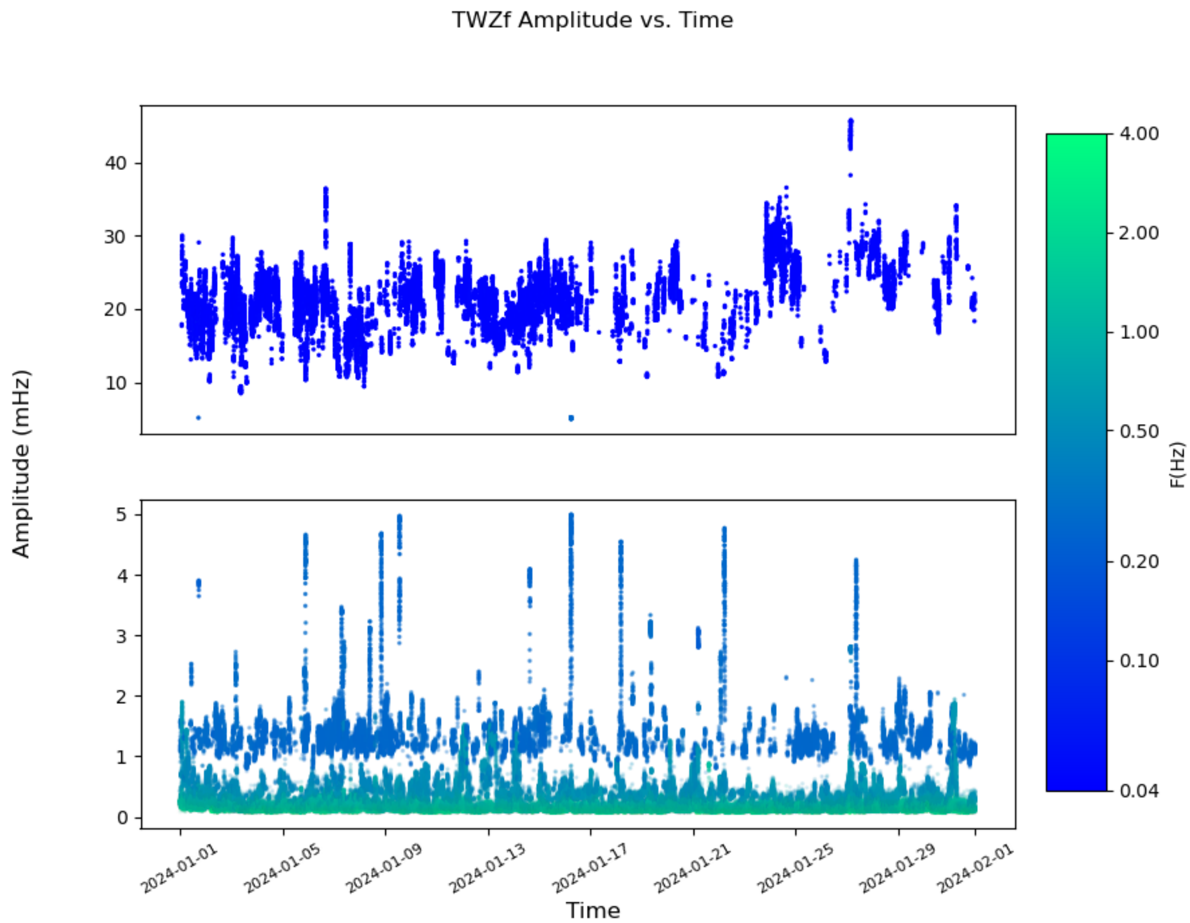


Note that the magnitude plot in the frequency (mHz) histograms is scaled to show the typical range of amplitude and does not usually show the 0.04 Hz mode amplitude as it is above the scale. This amplitude is shown in the time series data.

Section 4.2 has time series plots. These show the results plotted against the day of the month along the x-axis. The plots use a colour coding (heat scale) for each data point to represent the mode frequency.

For each variable analyzed there are 3 time series plots, the first just shows the mode frequency detected (the heat scale does not add any information to this plot but is retained for consistency), the second shows the amplitude recorded and the 3rd shows the decay time expressed as the number of oscillation cycles at that modal frequency. Expressing the decay time in cycles provides a better indication of whether the decay time is a problem or not.

For the same TWZ frequency results as shown in the histograms above the amplitude time series plot is shown below (note the y-axis scale is split into 2 plots to show the higher magnitude of the 0.04 Hz mode) :

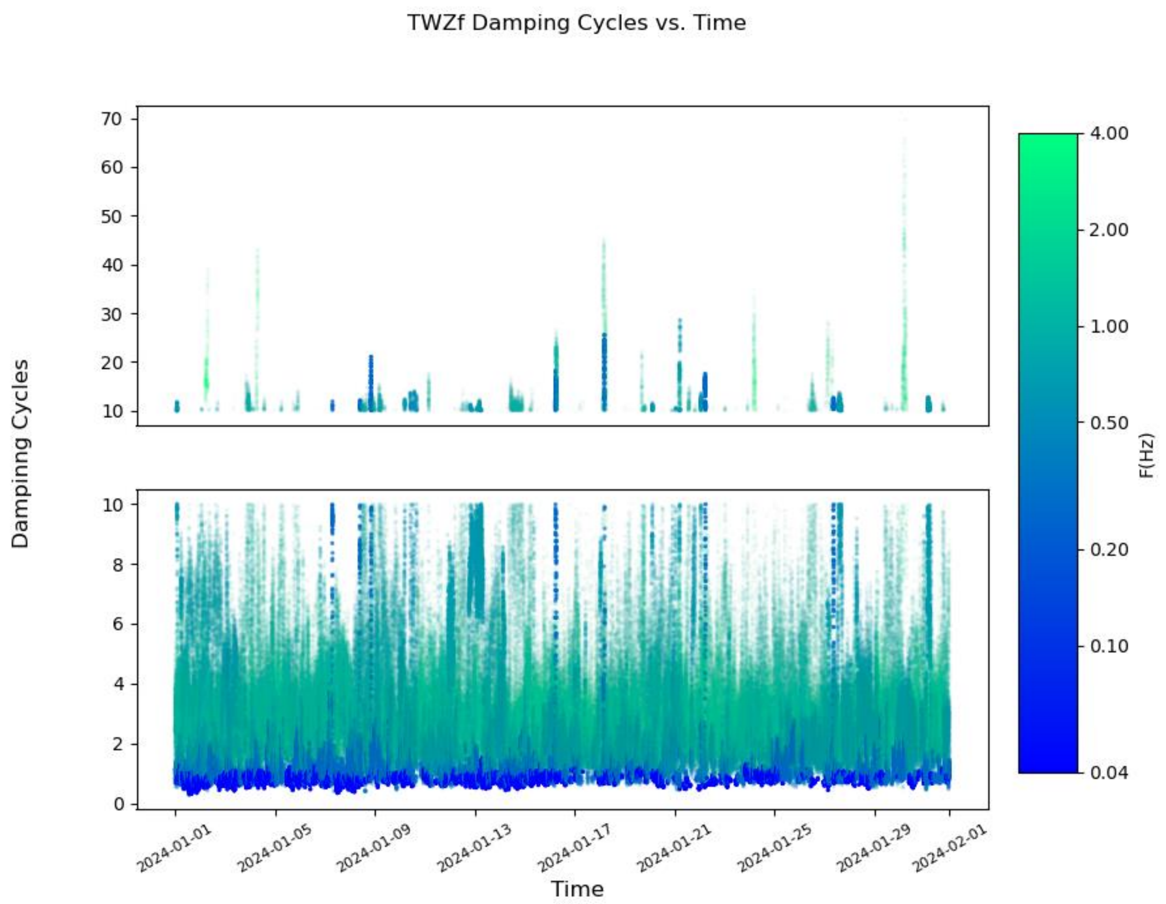


The heat scale shows the modal frequency of the particular amplitude result, in this case the 5mHz peaks are all at or close to the 0.25Hz mode.

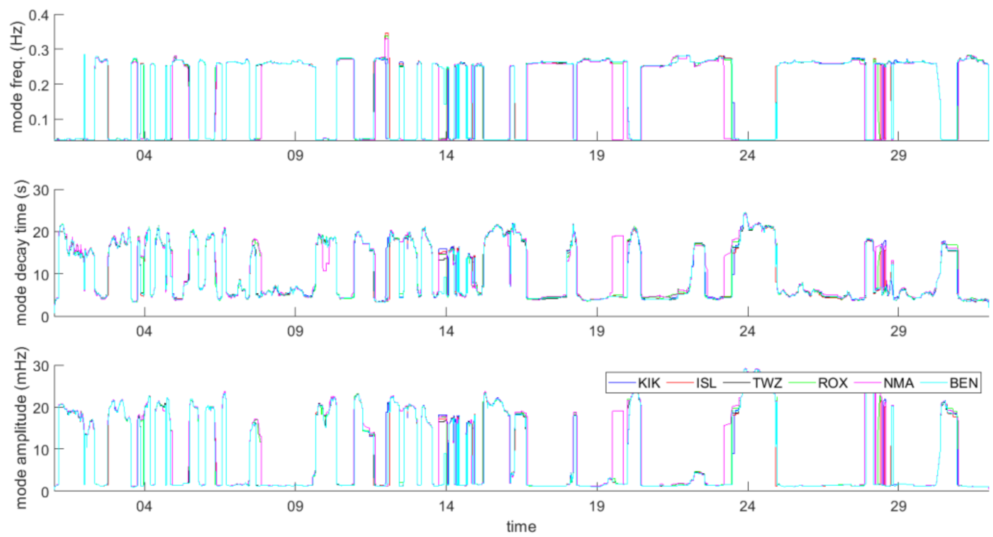
The histogram identifies that there are results with 5 mHz amplitude at this frequency - the time series plot indicates the spread of these peak occurrences through the month and also shows any other characteristics at that frequency – such as the 'normal' amplitude.

The corresponding damping cycles time series plot is shown below.

The relatively high decay times of the 0.04 Hz mode are seen to be all below 2 cycles at that modal frequency. When decay times are say 40 or 50 cycles at a particular modal frequency there may be more cause for concern.



The pre-2024 monthly reports would have displayed the time series data as a smoothed trend with a frequency band (with all sites plotted together) i.e for the 0 to 0.4 Hz band :



The new method of plotting shows all the data – this shows the full-month time series behaviour of all modes – and overcomes the issue of only showing the 'worst' result within a band (which causes the plot above to alternately show the 0.04 Hz mode and the 0.25 Hz mode).

4 Detailed plots for August 2024

4.1 Mode frequency histograms

Remark: the frequency histograms are shown for a frequency range [0.04 4Hz]

4.1.1 PMU Frequency Data

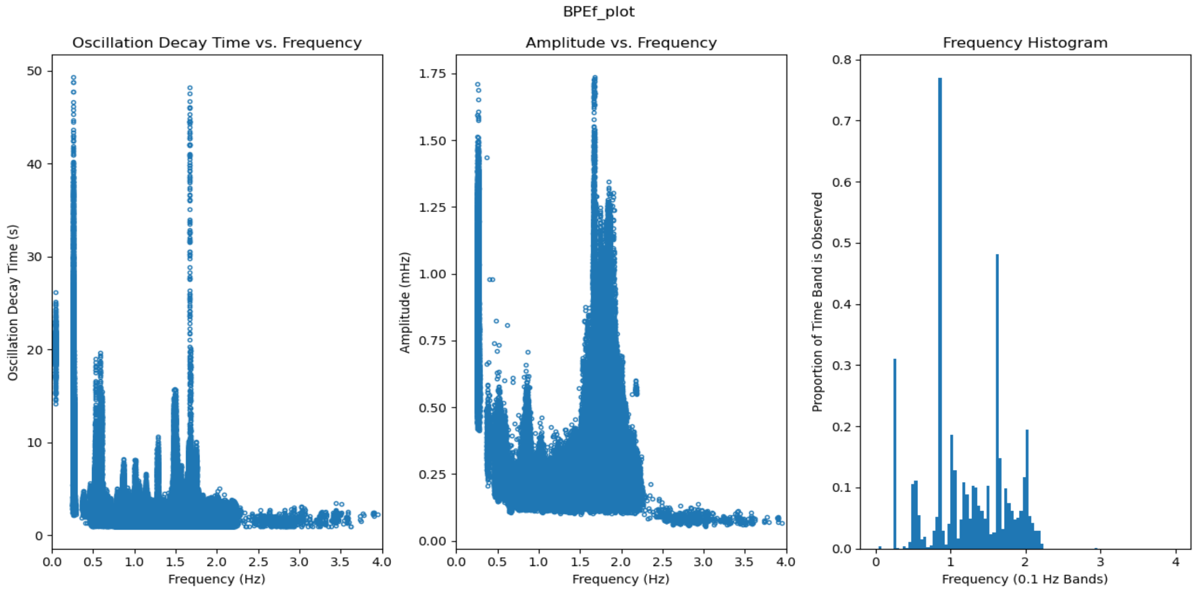


Figure 1: Bunnythorpe mode damping, mode amplitude, and frequency histogram using frequency data

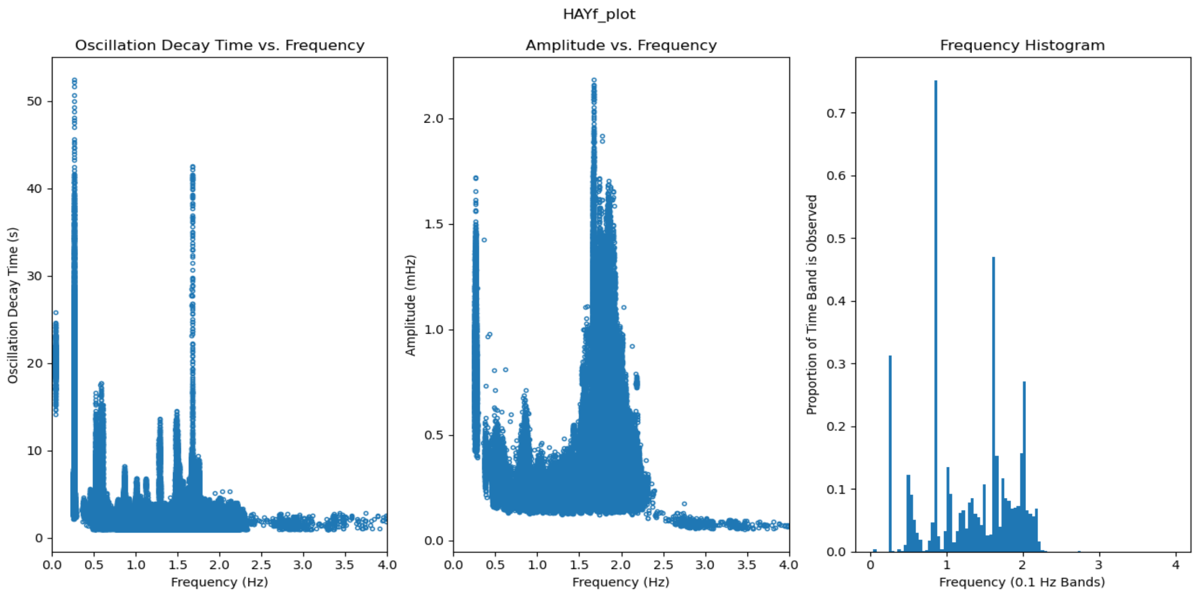


Figure 2: Haywards mode damping, mode amplitude, and frequency histogram using frequency data

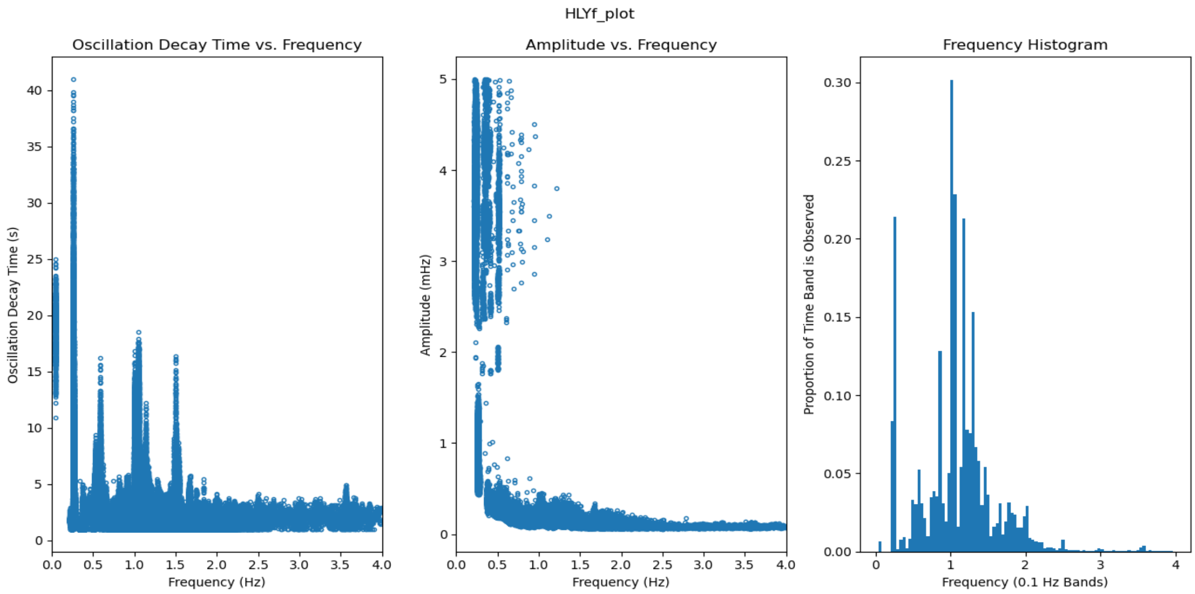


Figure 3: Huntly mode damping, mode amplitude, and frequency histogram using frequency data

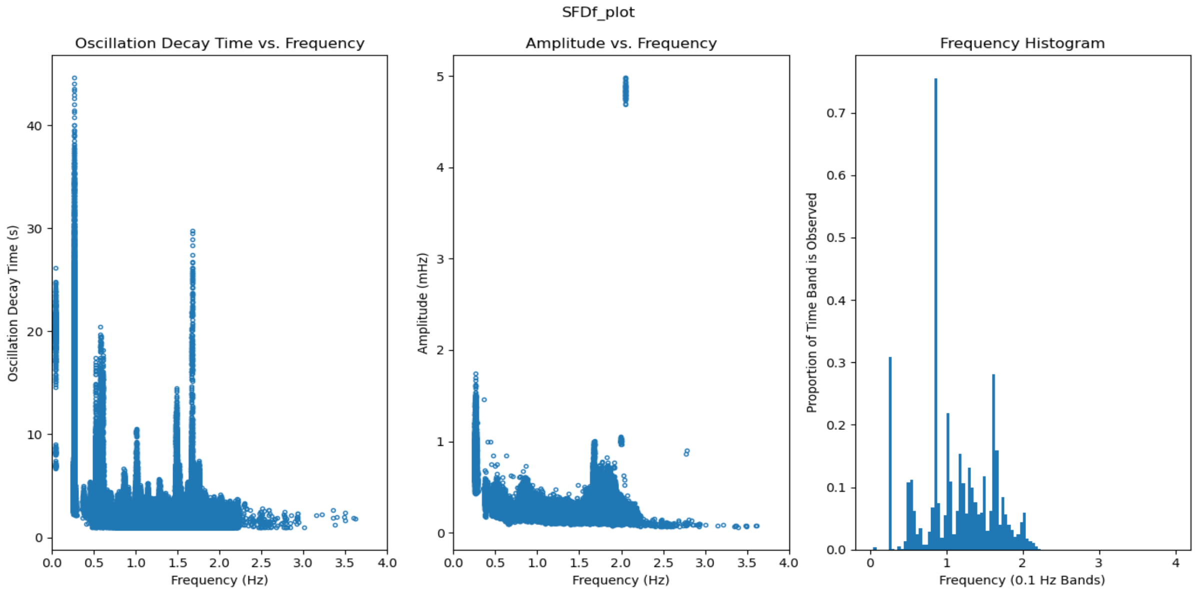


Figure 4: Stratford mode damping, mode amplitude, and frequency histogram using frequency data

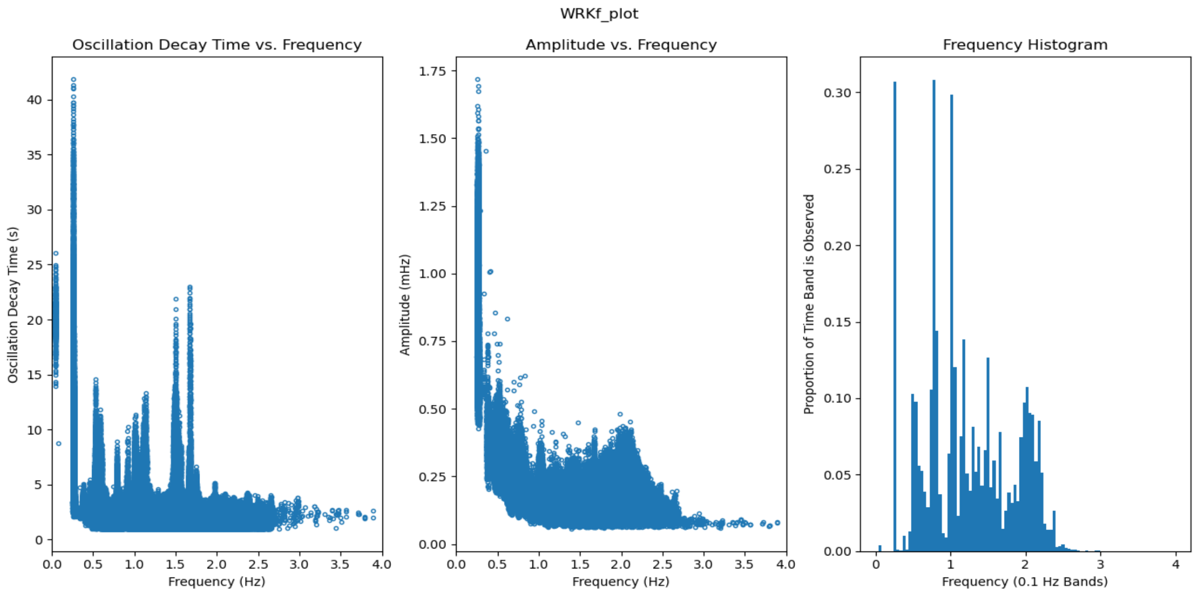


Figure 5: Wairakei mode damping, mode amplitude, and frequency histogram using frequency data

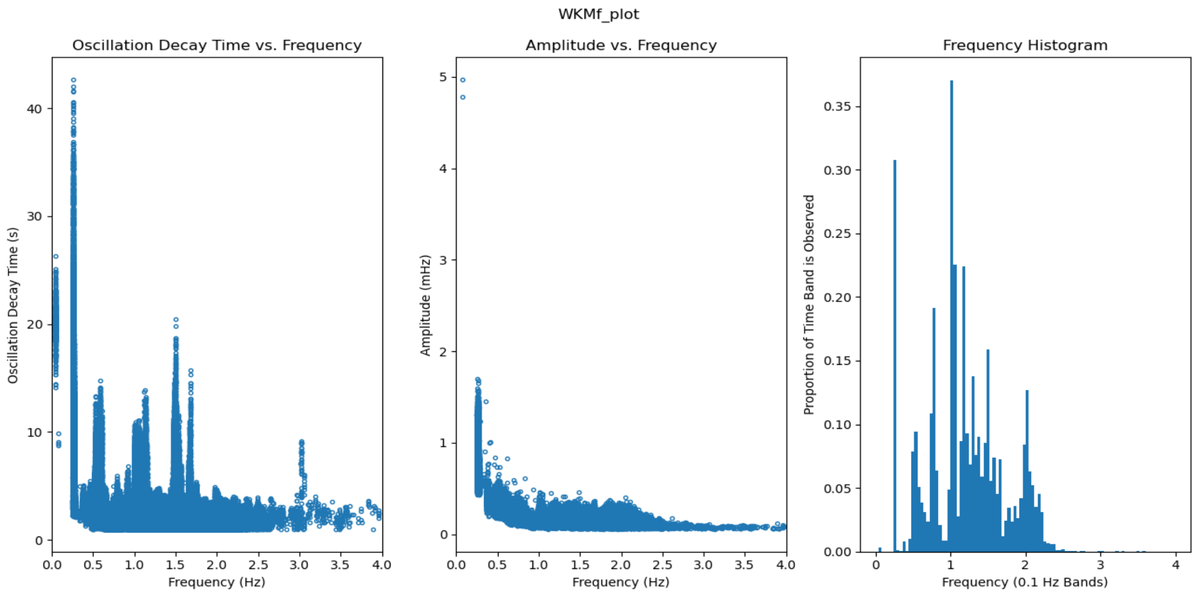


Figure 6: Whakamaru mode damping, mode amplitude, and frequency histogram using frequency data

4.1.2 PMU Active Power Data

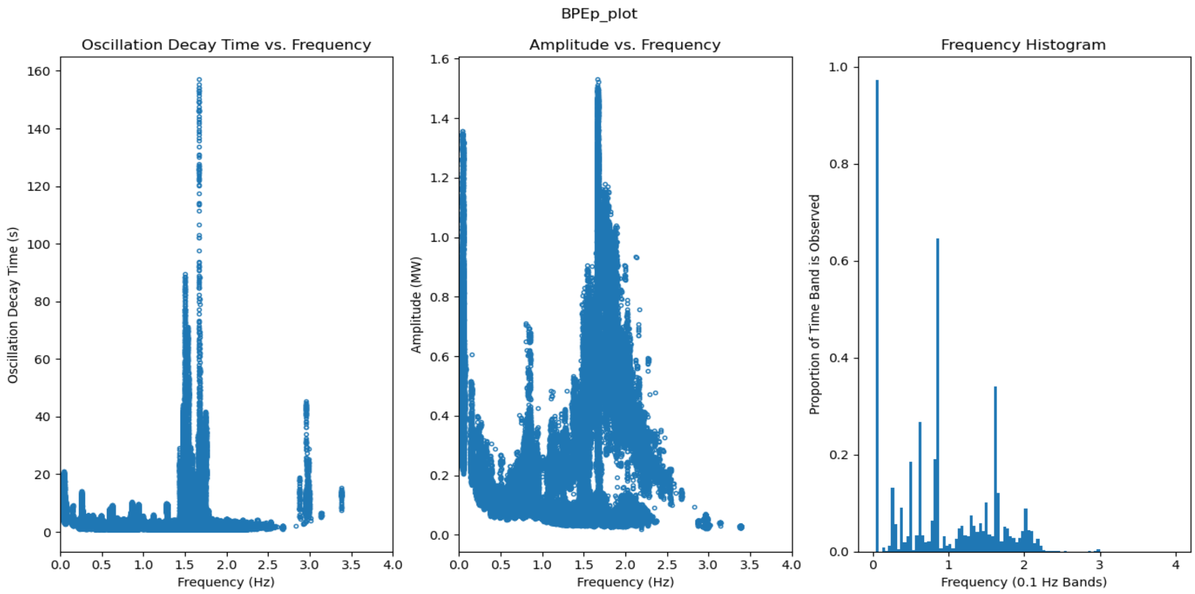


Figure 7: Bunnythorpe mode damping, mode amplitude, and frequency histogram using active power data

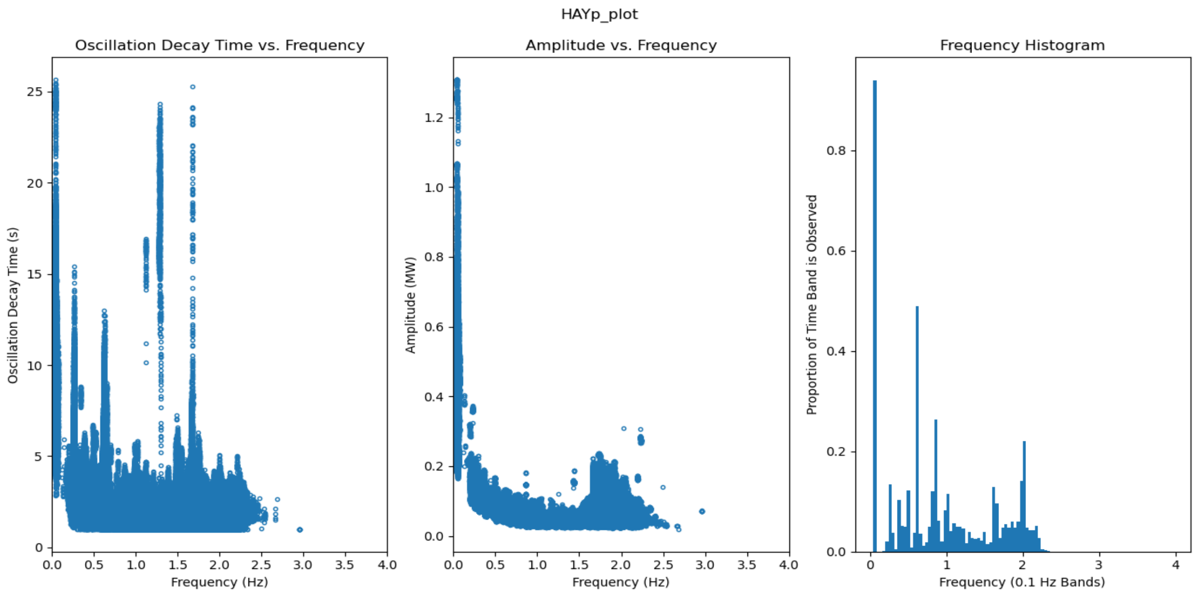


Figure 8: Haywards mode damping, mode amplitude, and frequency histogram using active power data

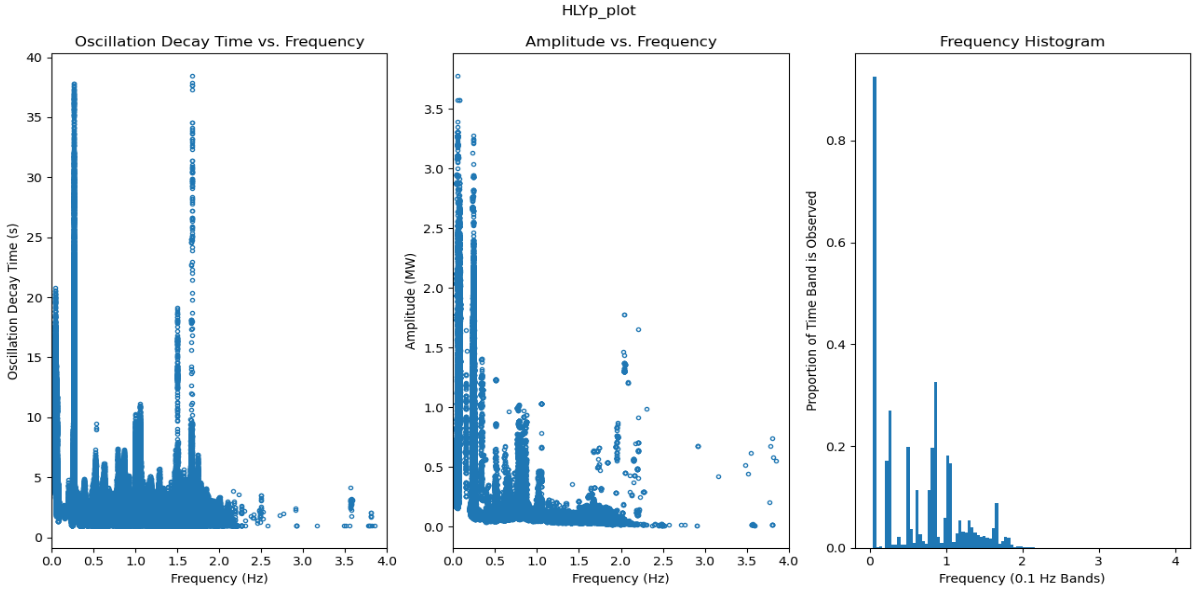


Figure 9: Huntly mode damping, mode amplitude, and frequency histogram using active power data

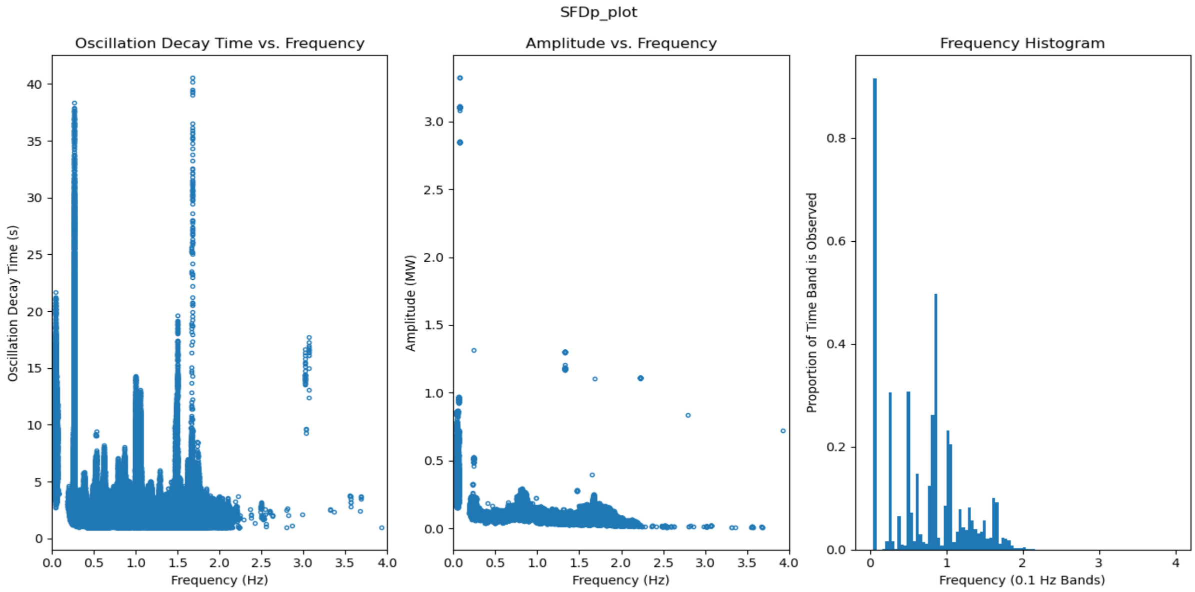


Figure 10: Stratford mode damping, mode amplitude, and frequency histogram using active power data

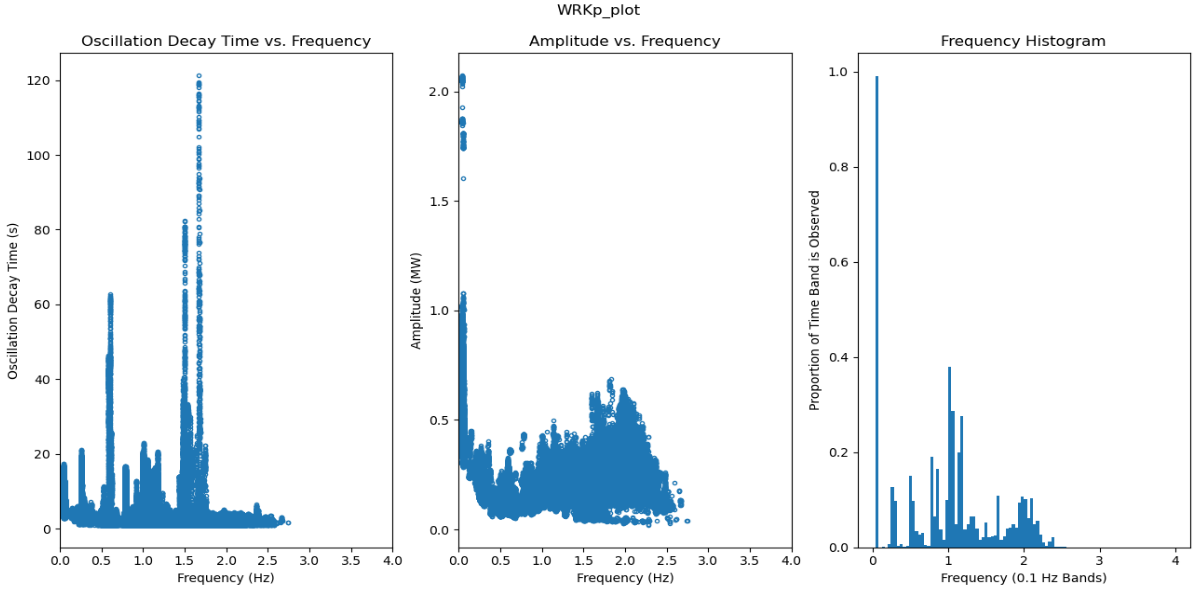


Figure 11: Wairakei mode damping, mode amplitude, and frequency histogram using active power data

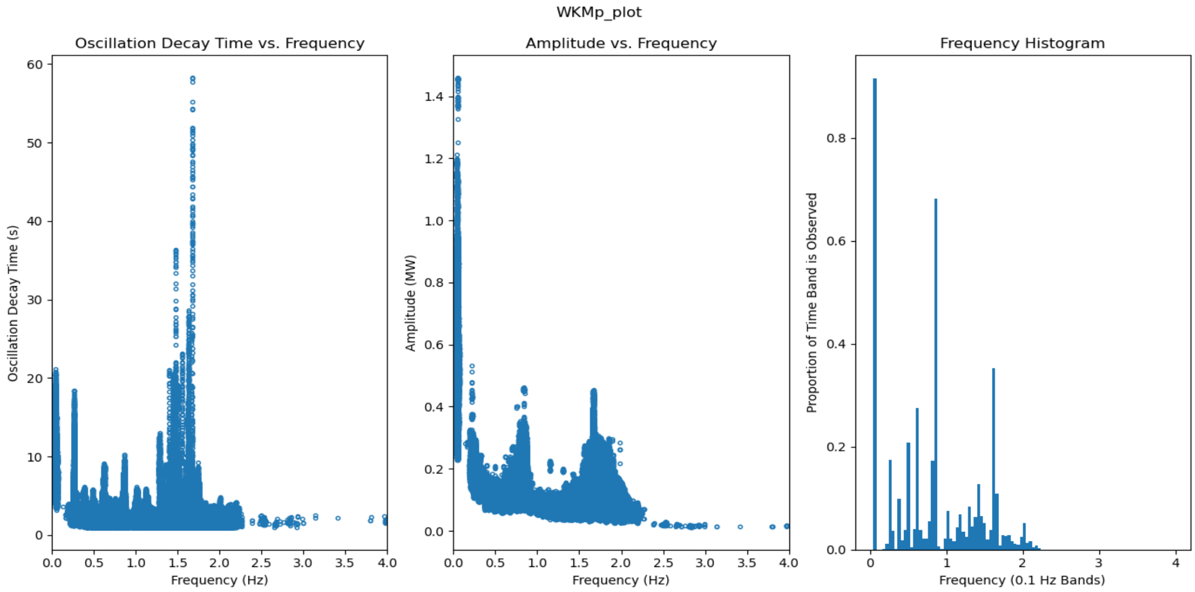


Figure 12: Whakamaru mode damping, mode amplitude, and frequency histogram using active power data

4.2 Time Series Plots

4.2.1 PMU Frequency Data

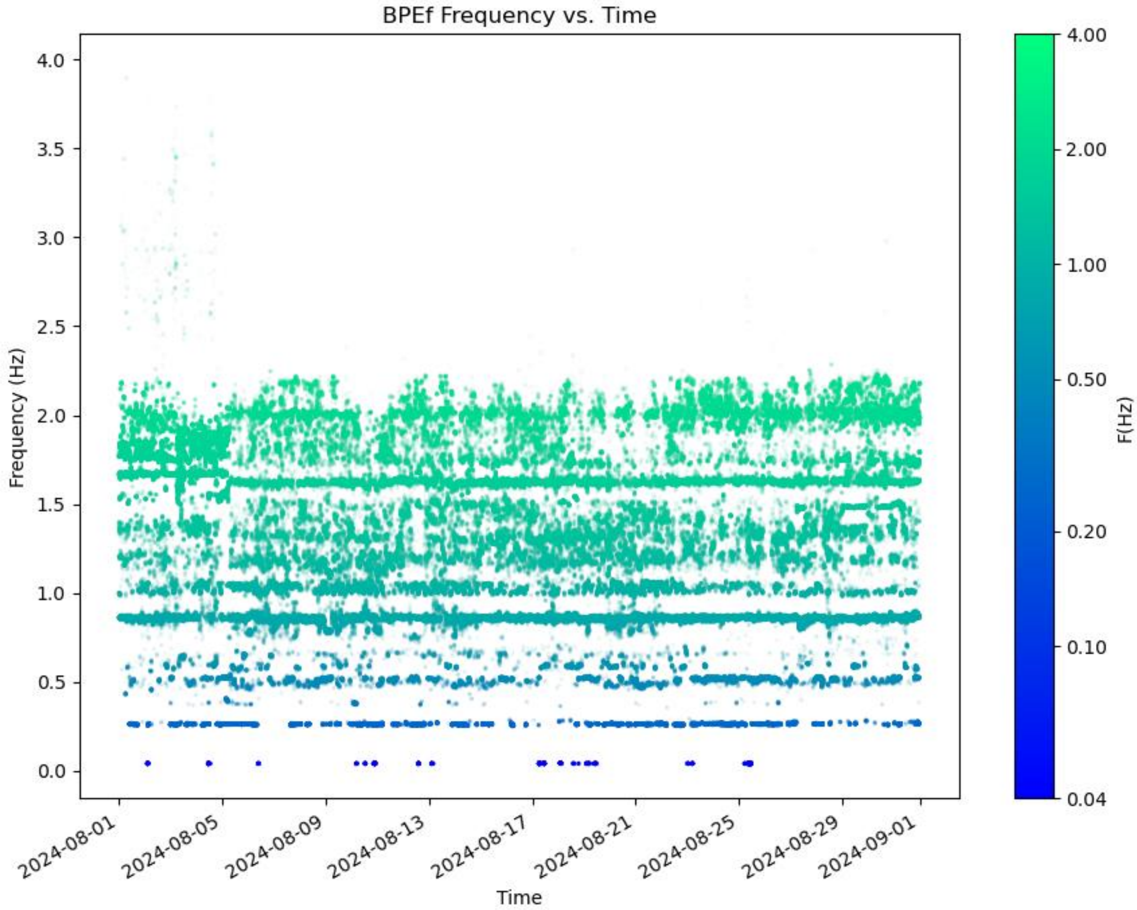


Figure 13: Bunnythorpe

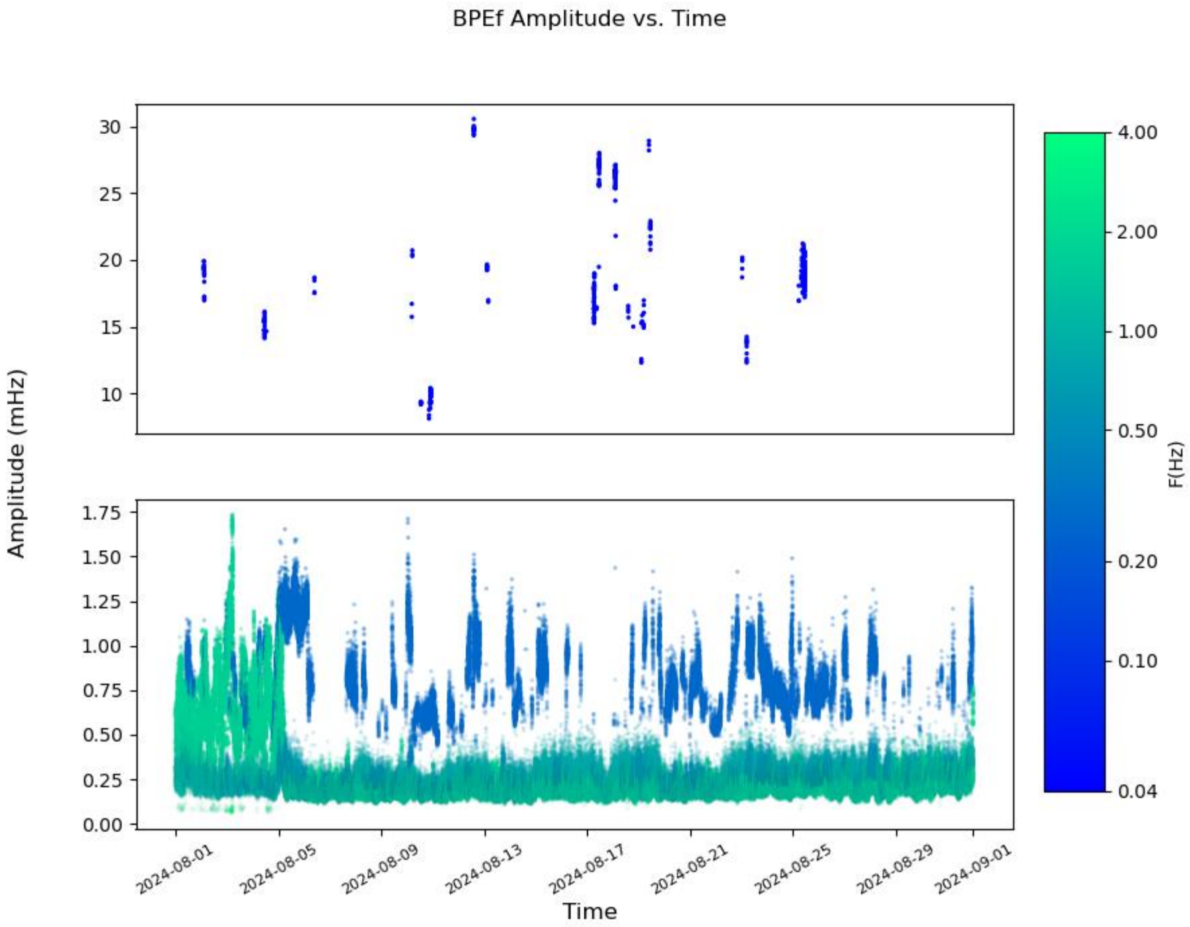


Figure 14: Bunnythorpe

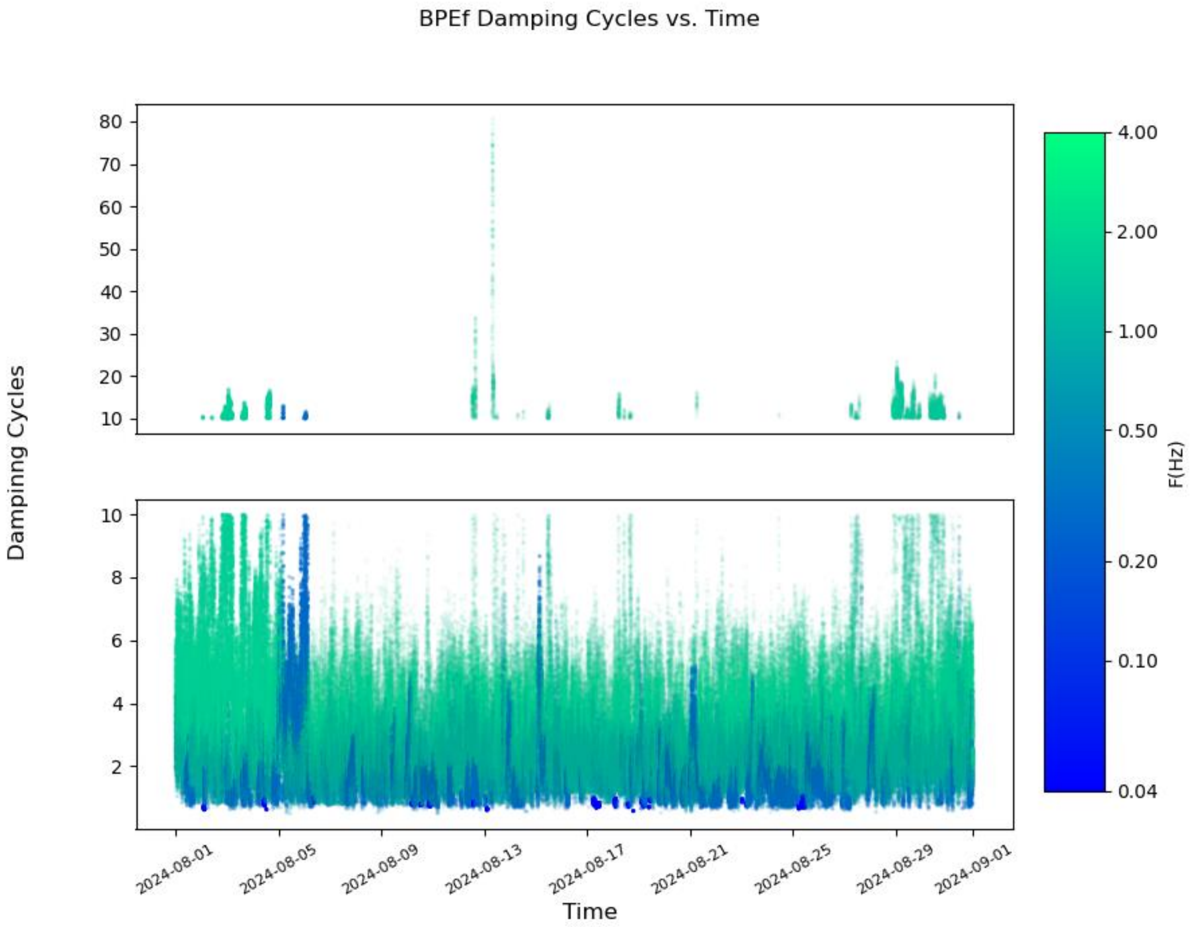


Figure 15: Bunnythorpe

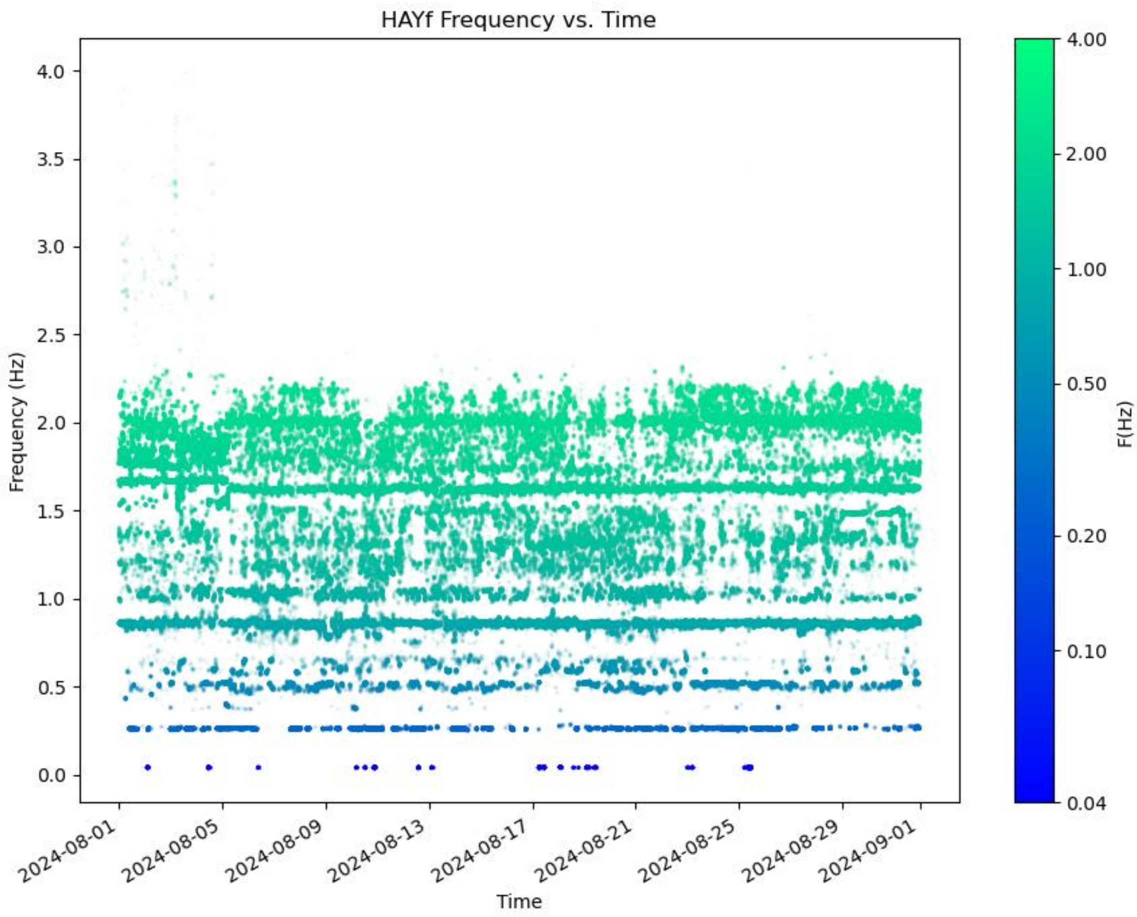


Figure 16: Haywards

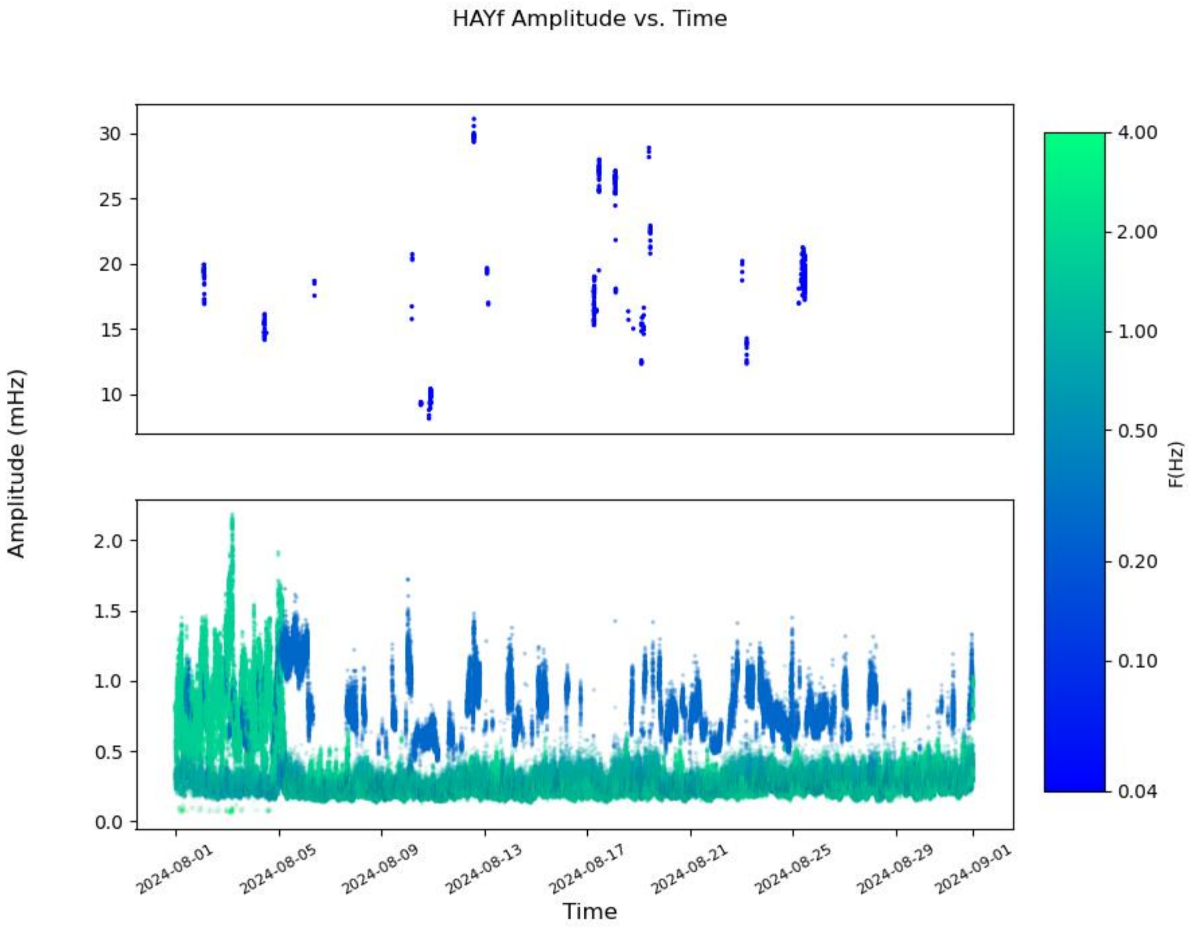


Figure 17: Haywards

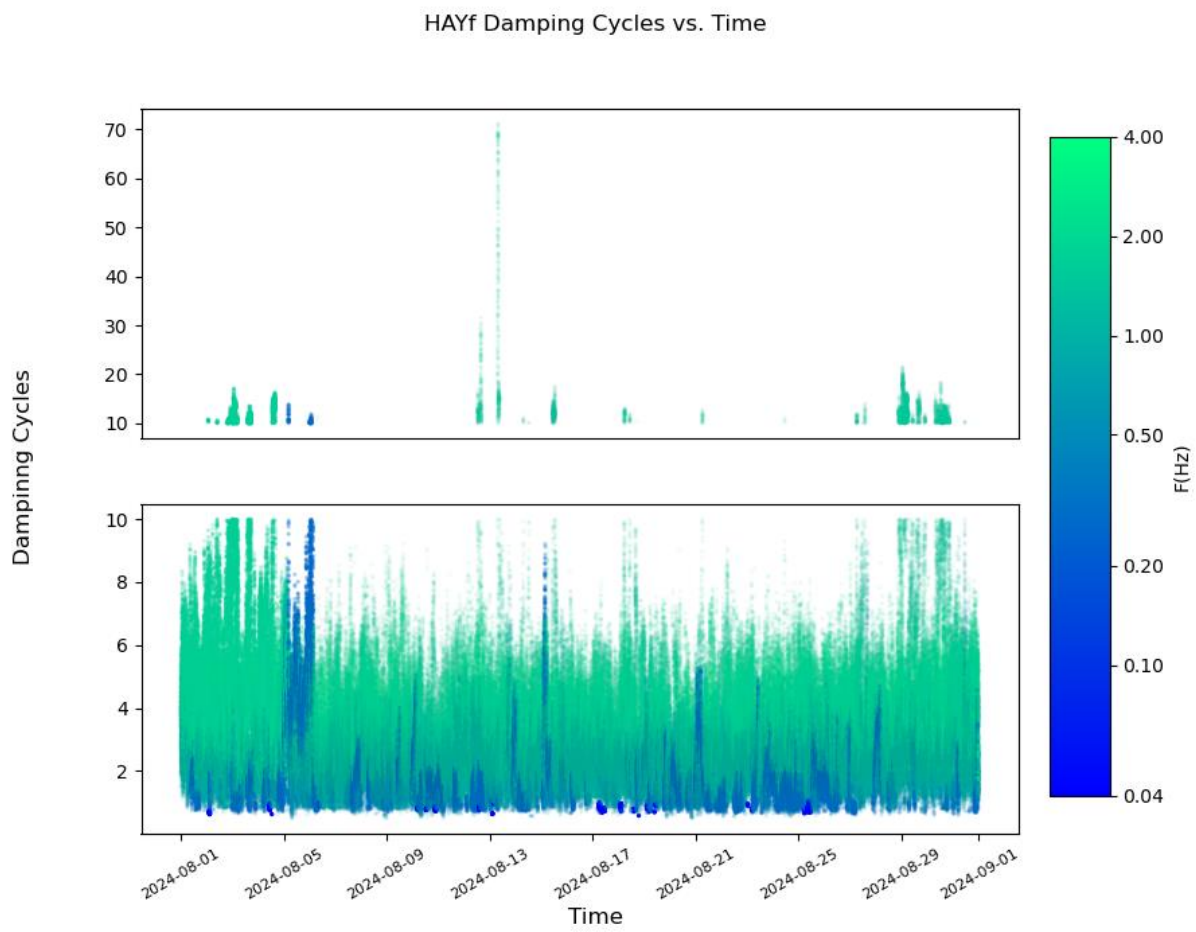


Figure 18: Haywards

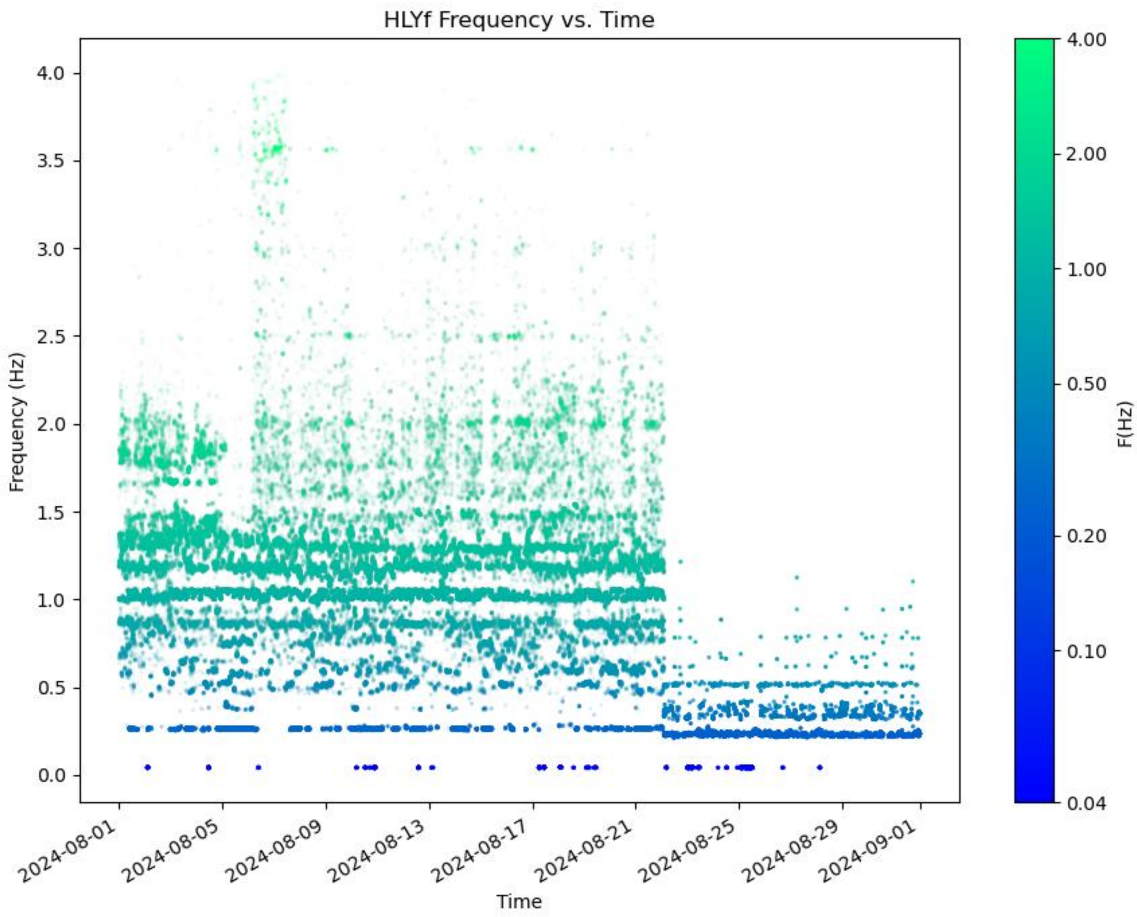


Figure 19: Huntly

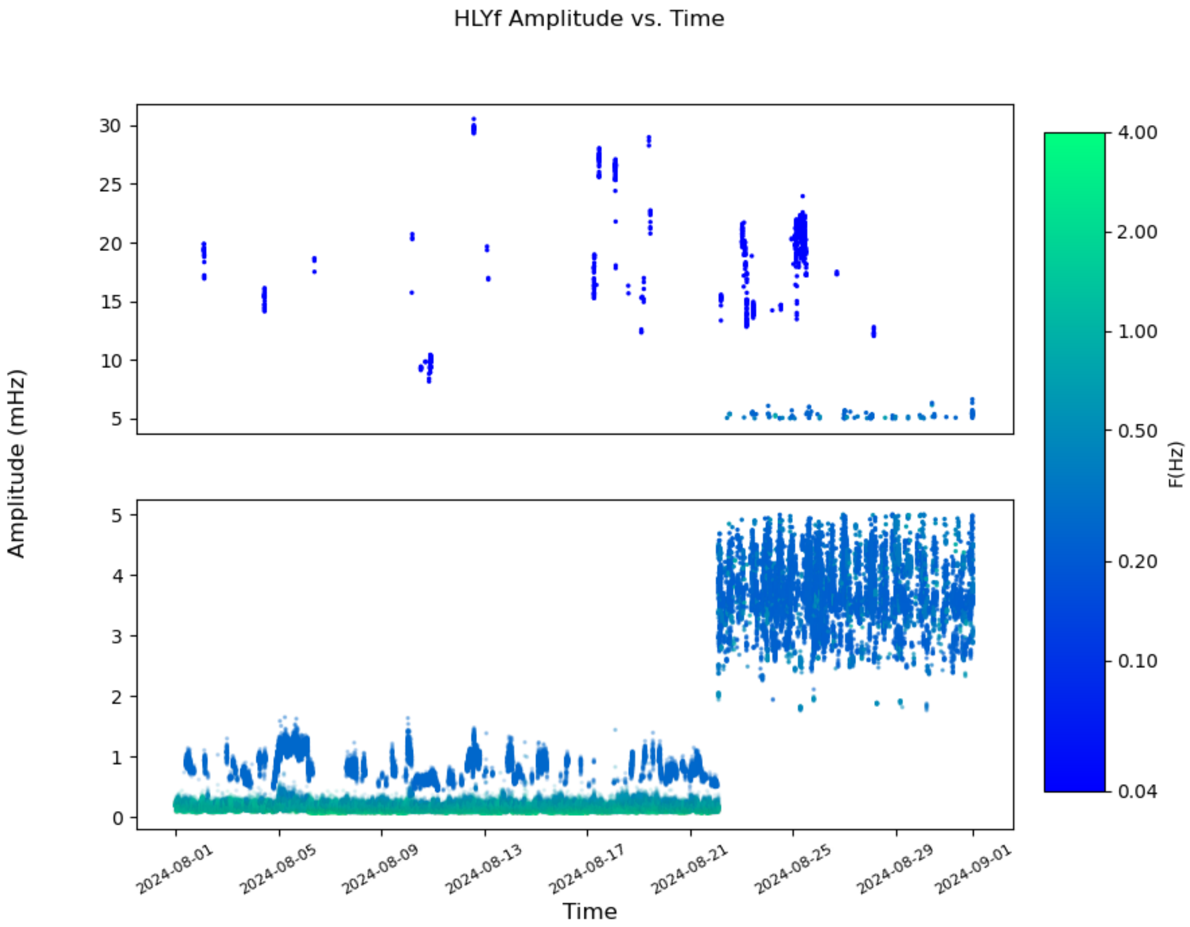


Figure 20: Huntly

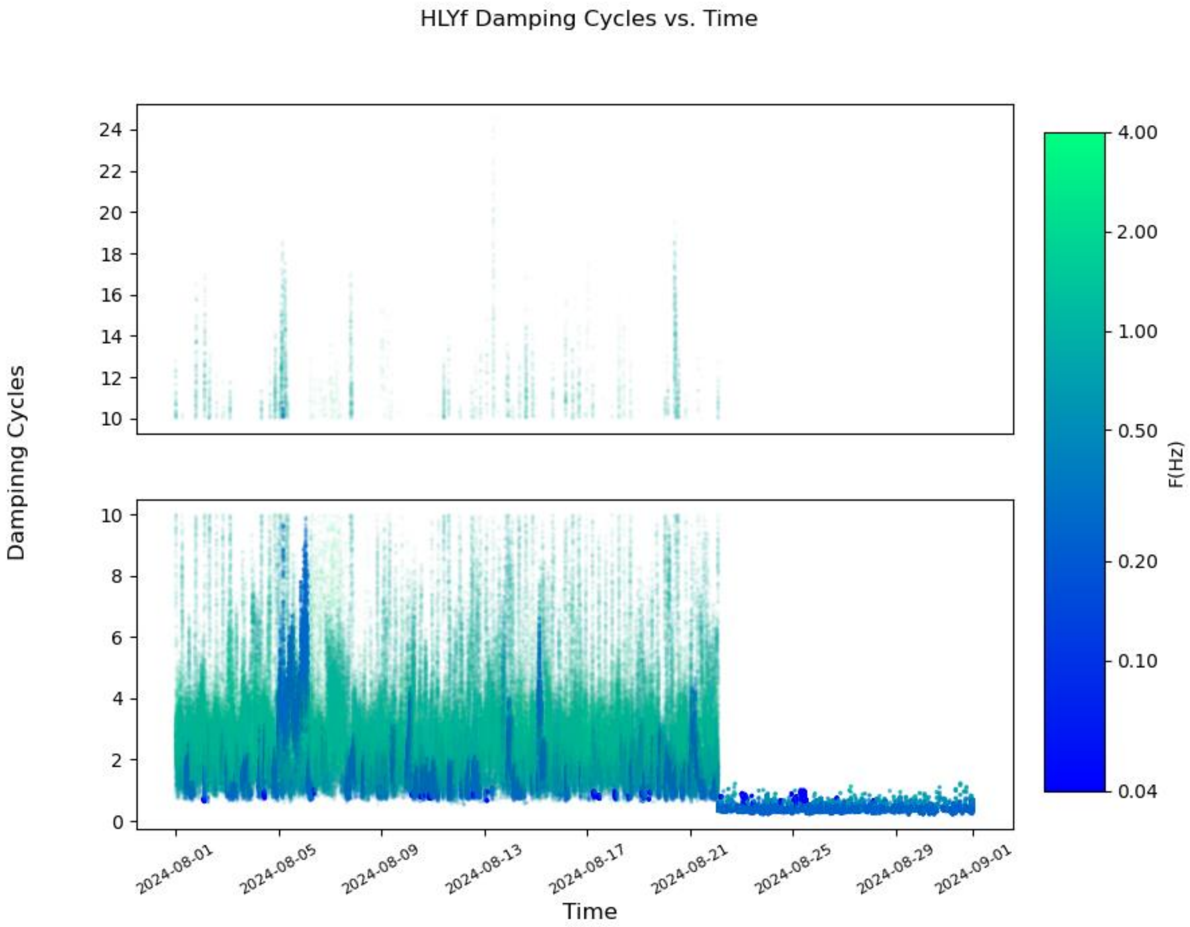


Figure 21: Huntly

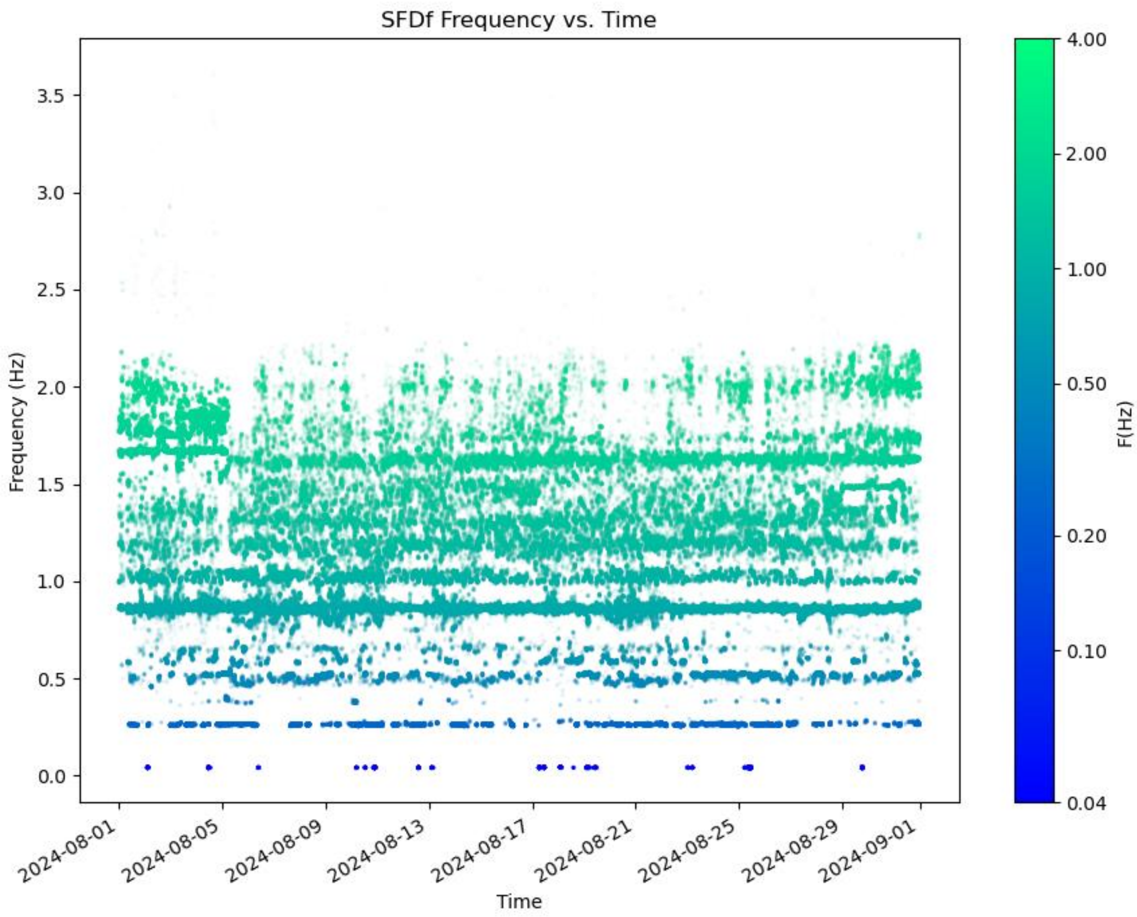


Figure 22: Stratford

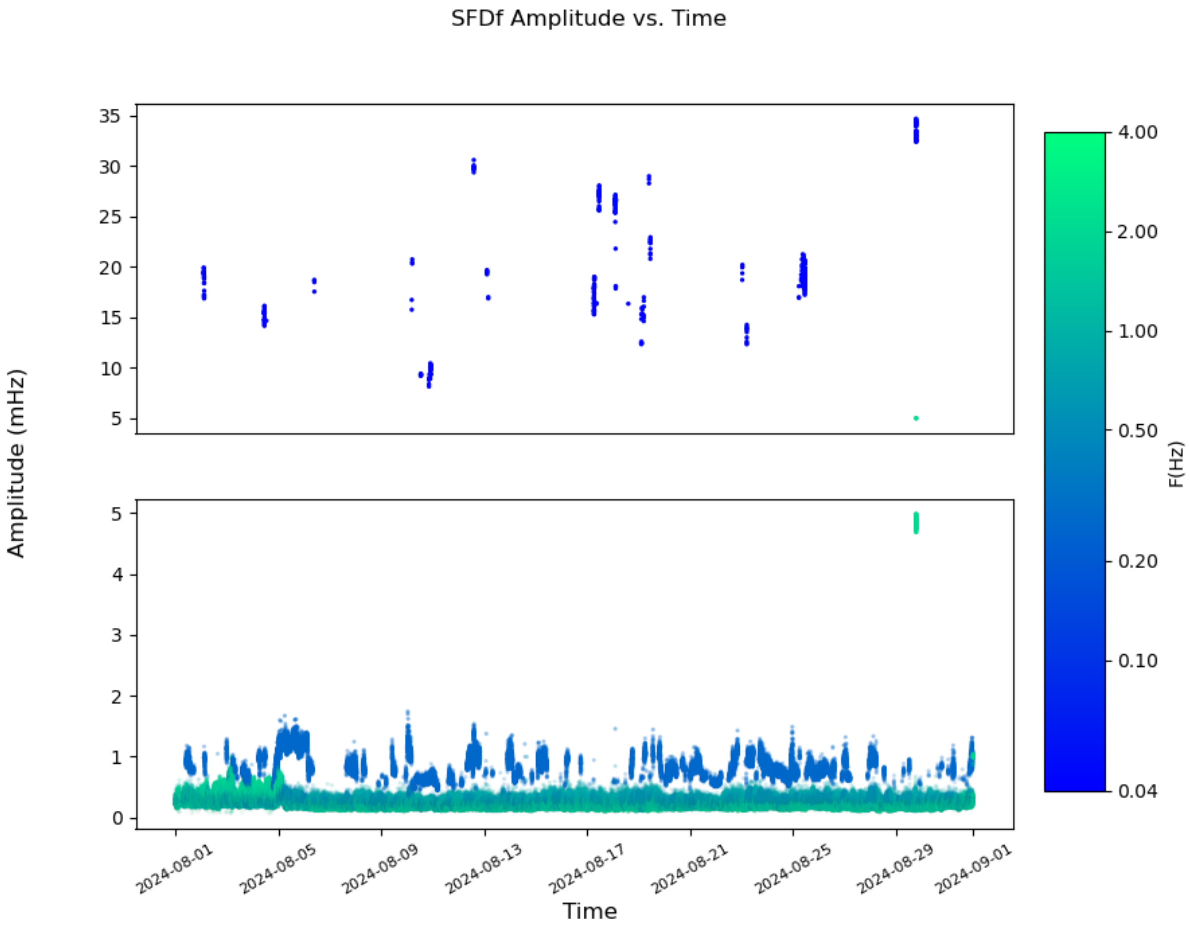


Figure 23: Stratford

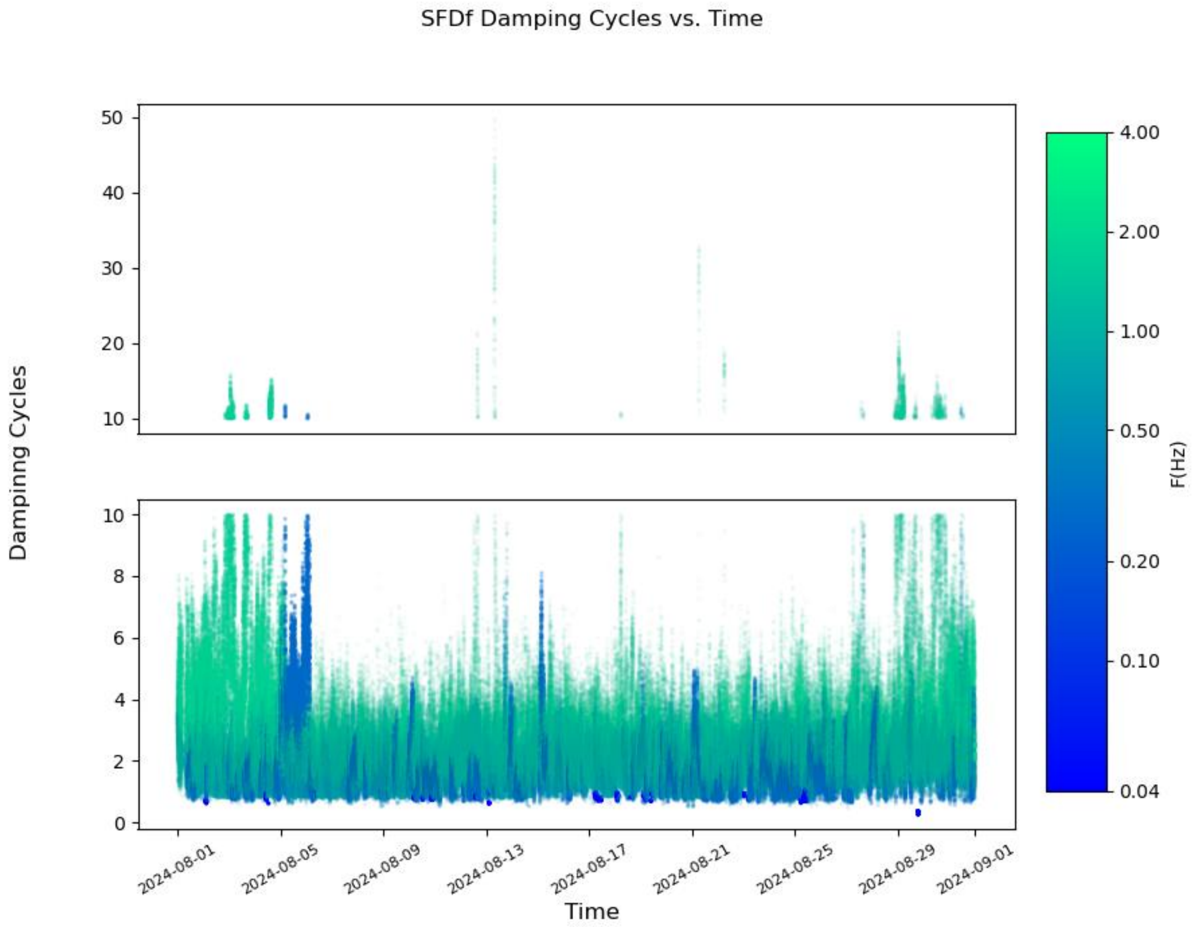


Figure 24: Stratford

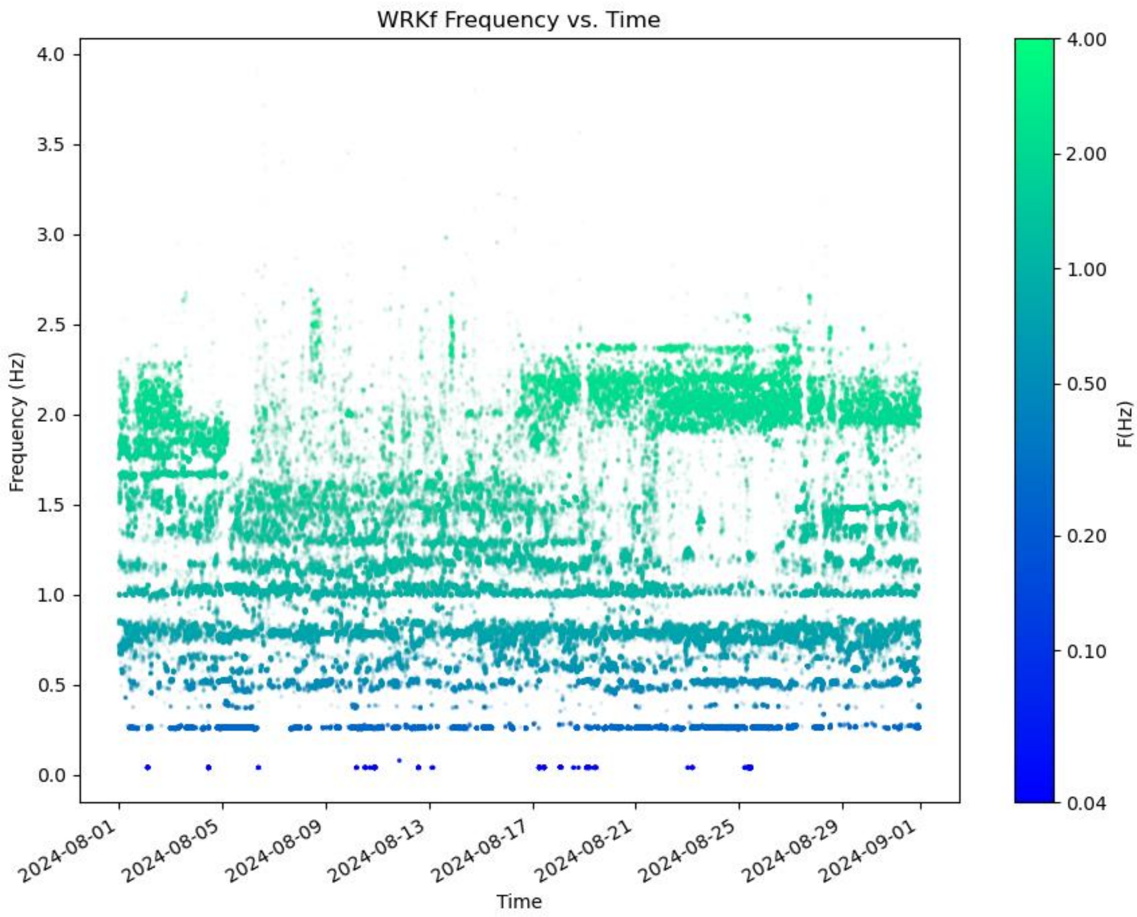


Figure 25: Wairakei

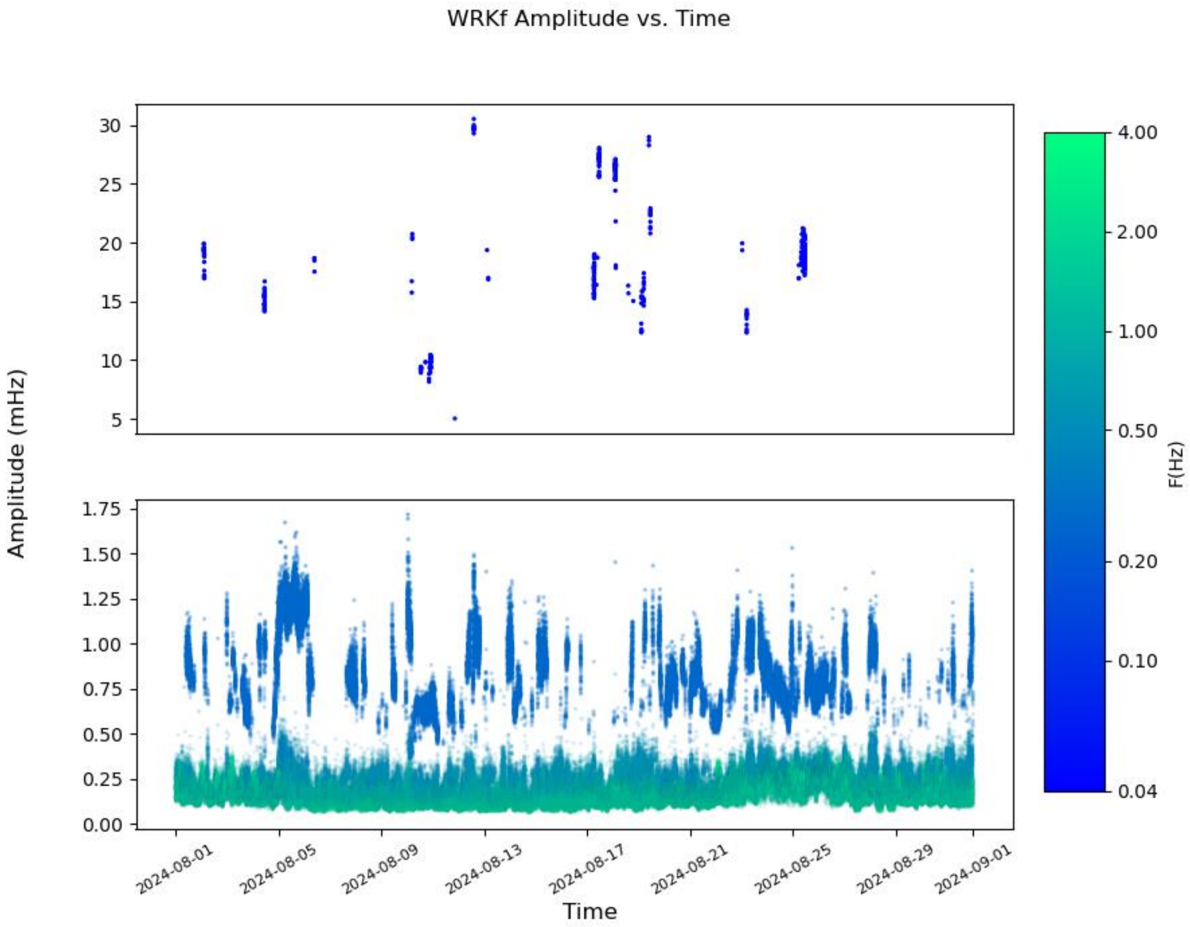


Figure 26: Wairakei

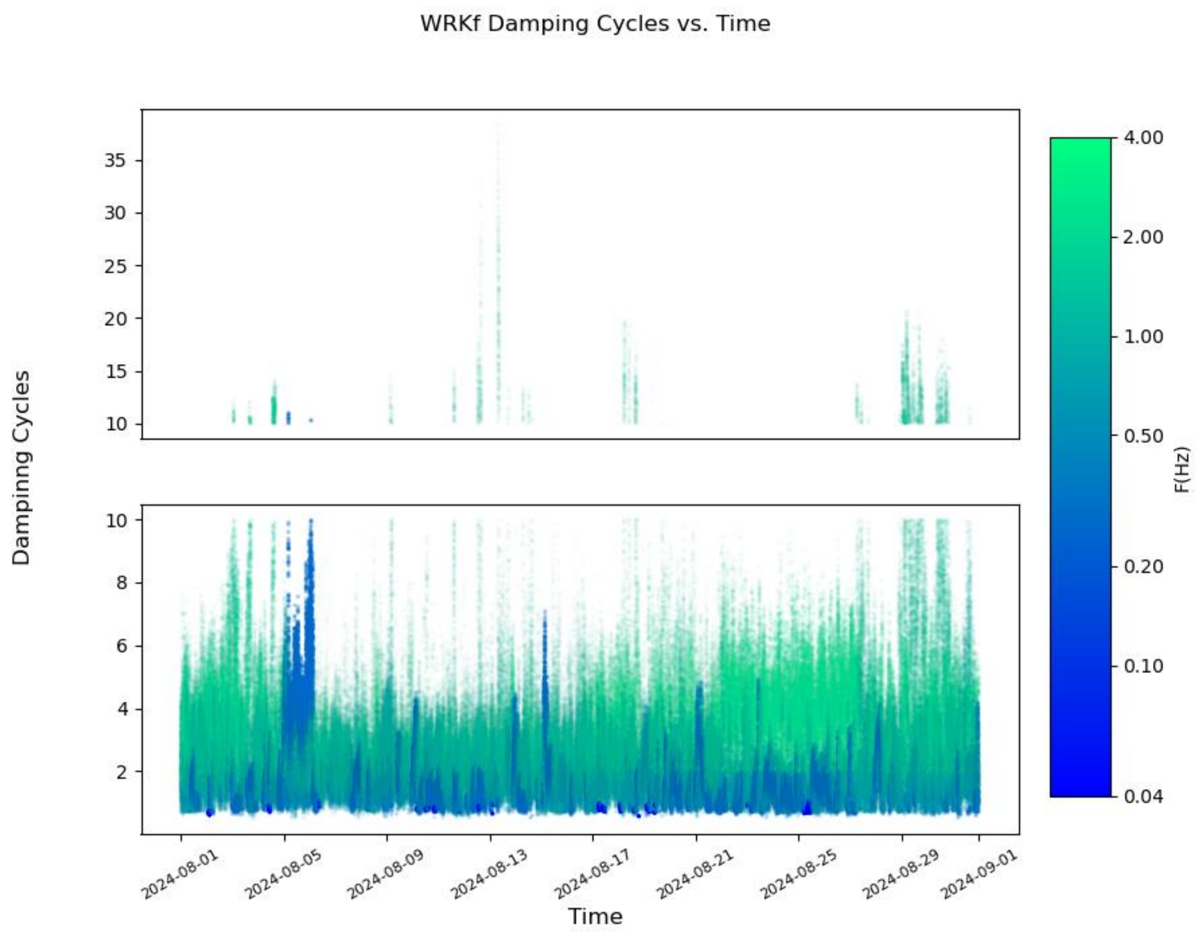


Figure 27: Wairakei

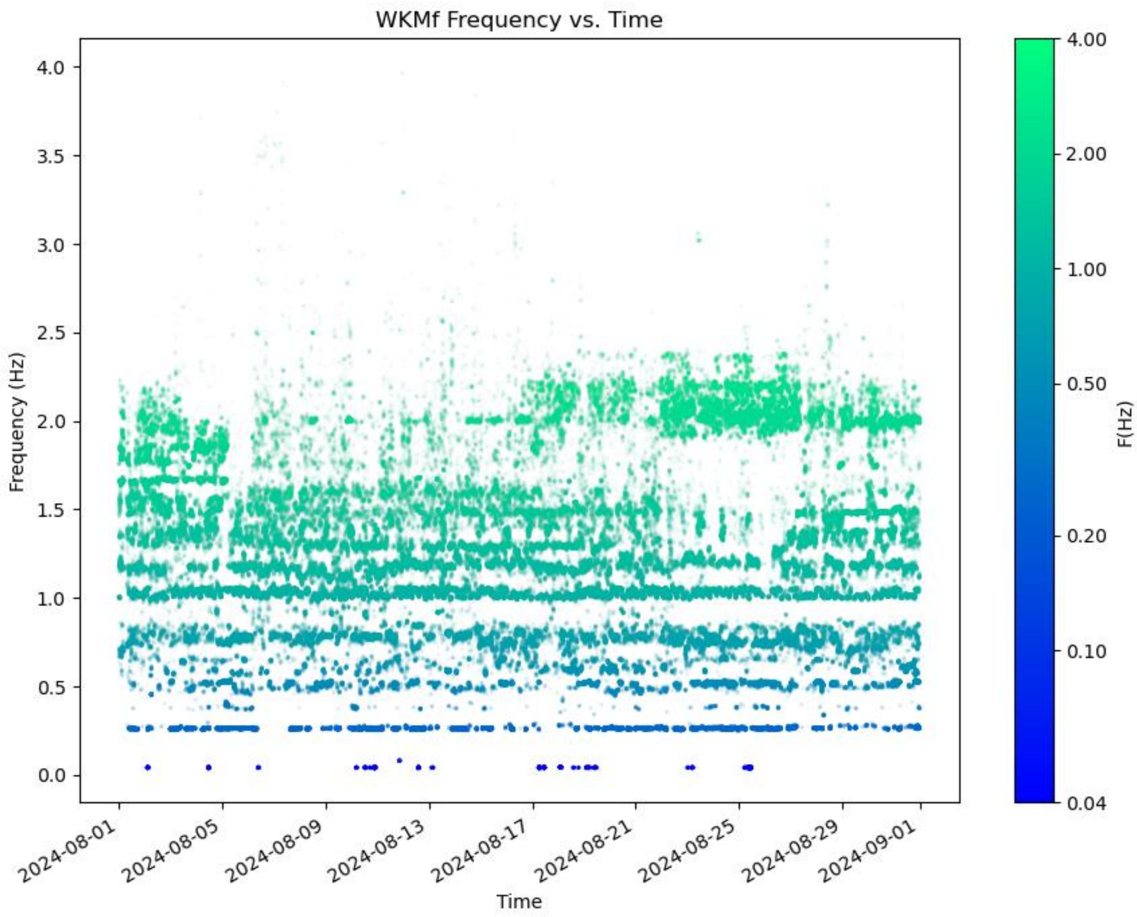


Figure 28: Whakamaru

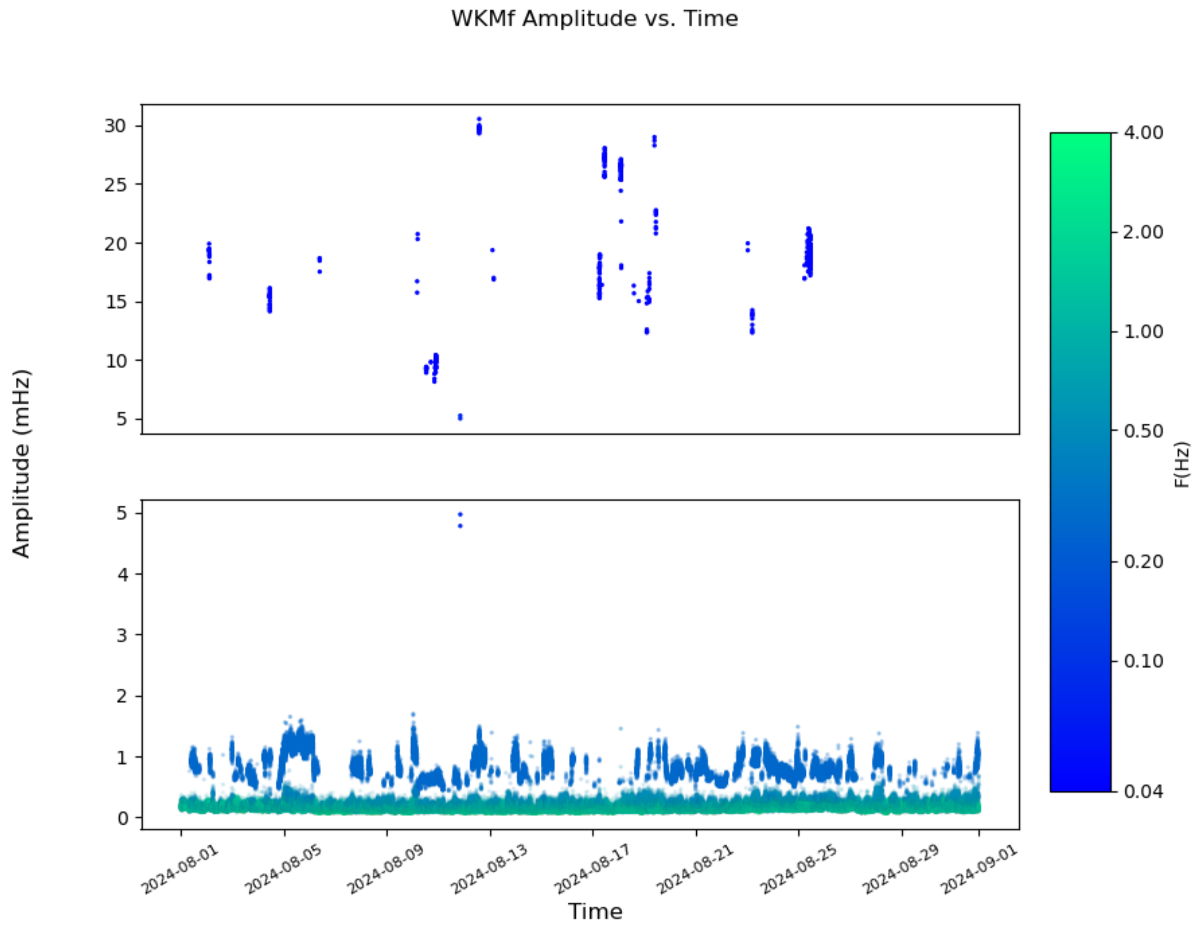


Figure 29: Whakamaru

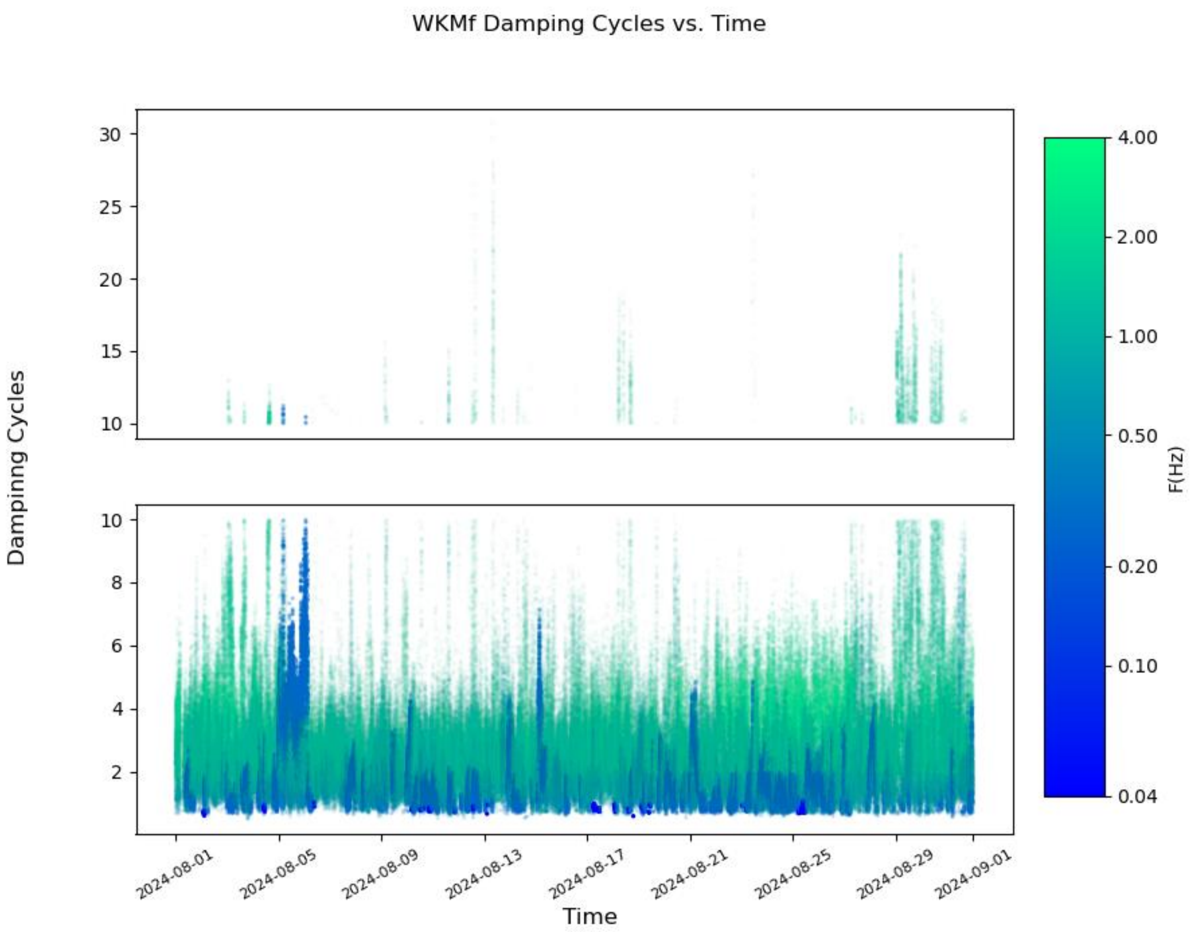


Figure 30: Whakamaru

4.2.2 PMU Active Power Data

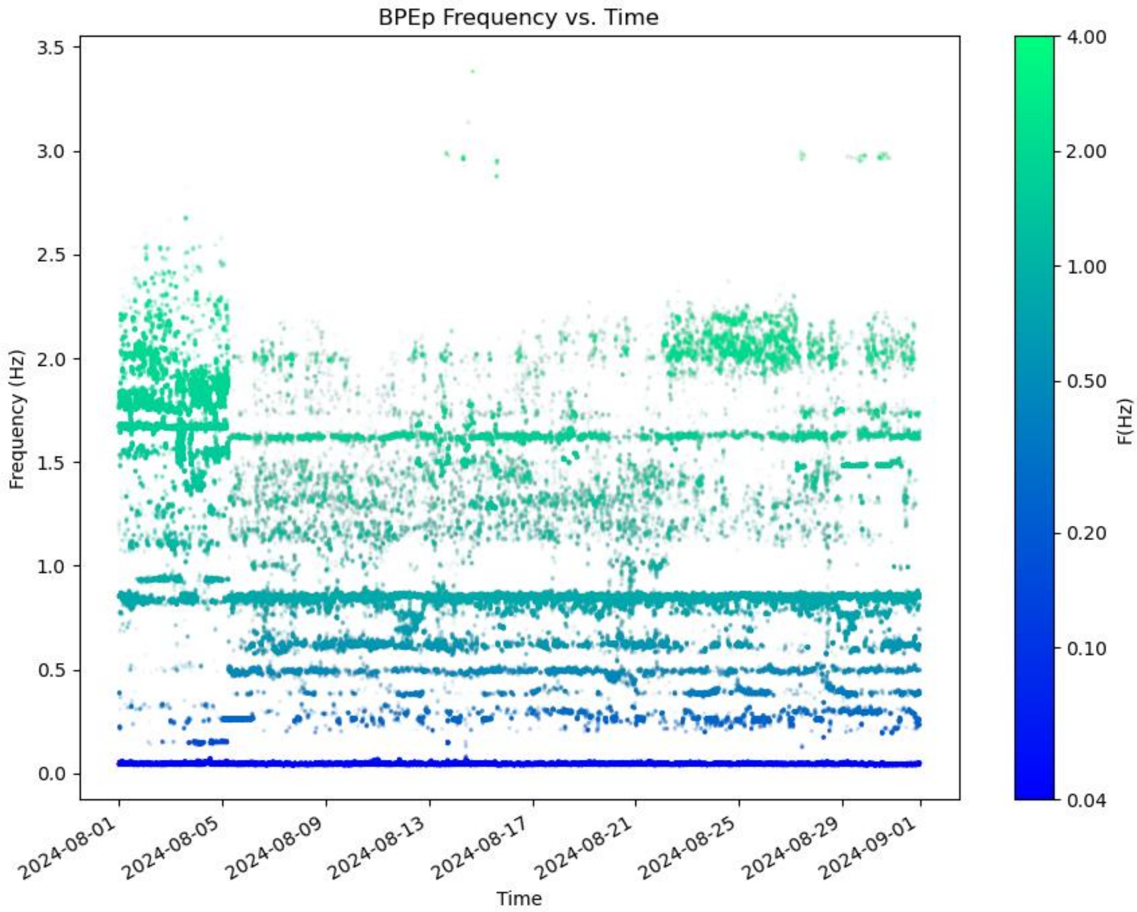


Figure 31: Bunnythorpe

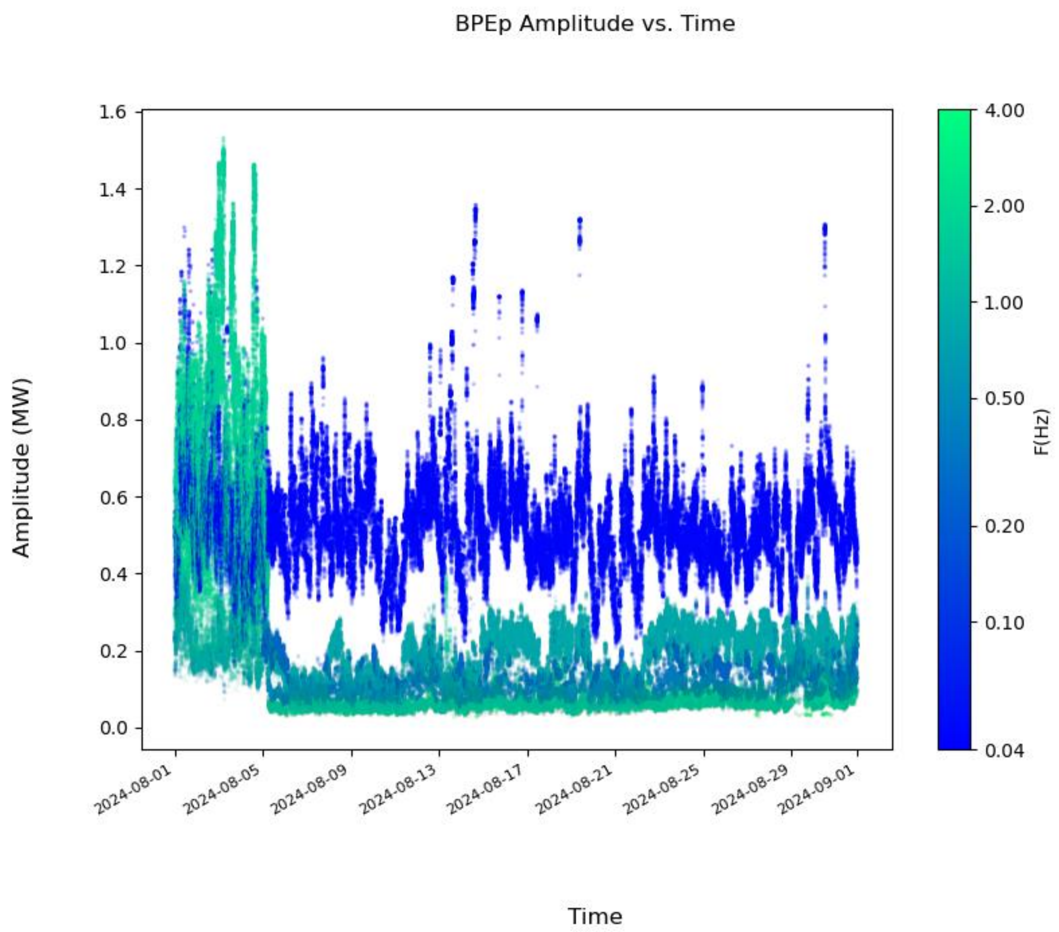


Figure 32: Bunnythorpe

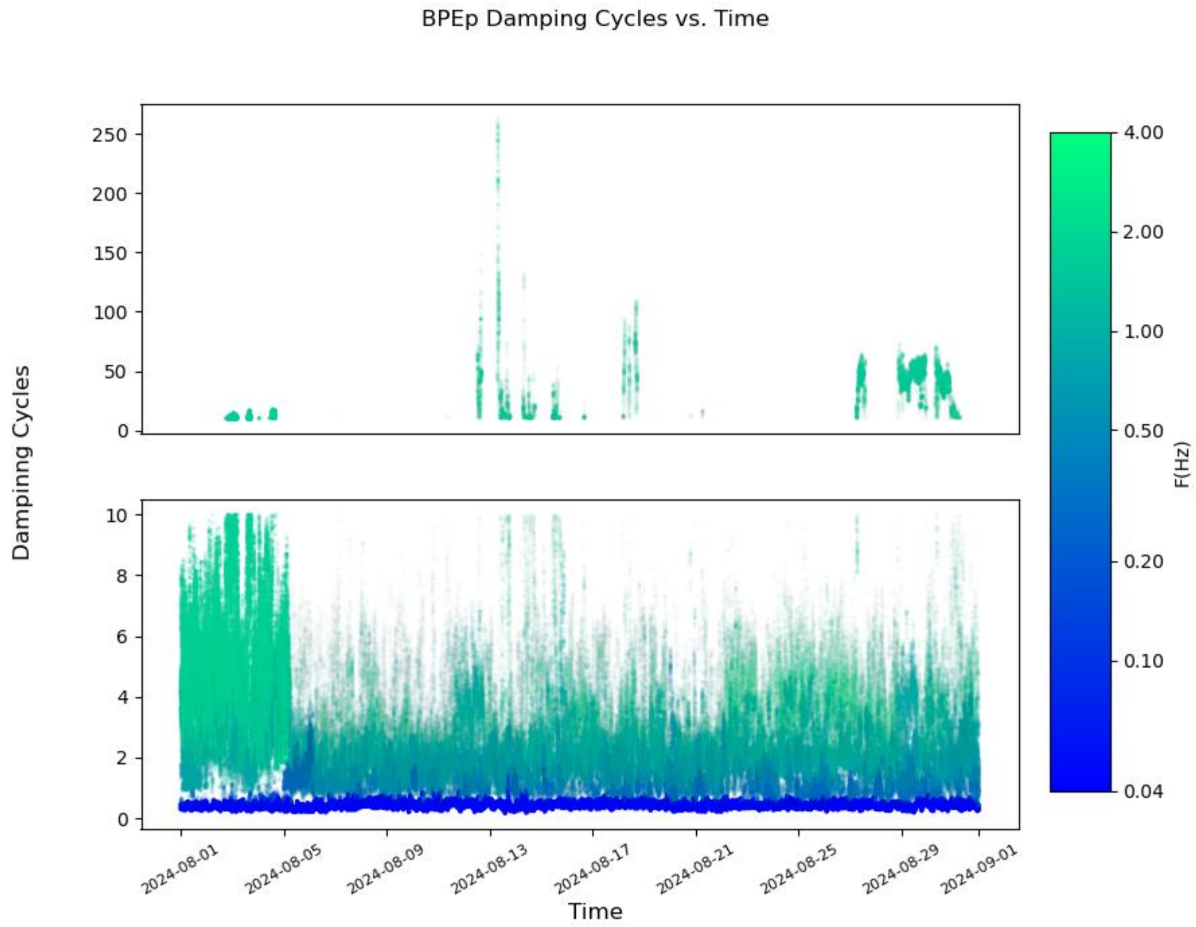


Figure 33: Bunnythorpe

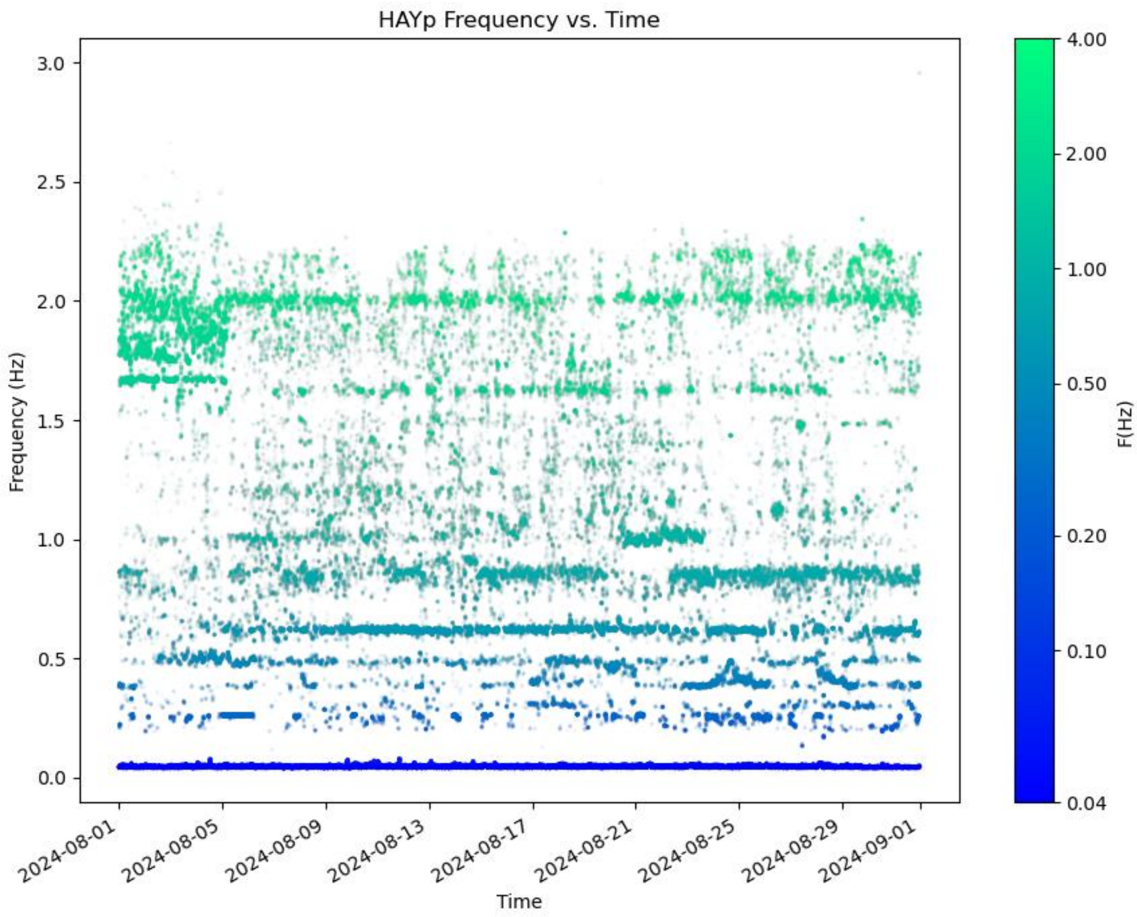


Figure 34: Haywards

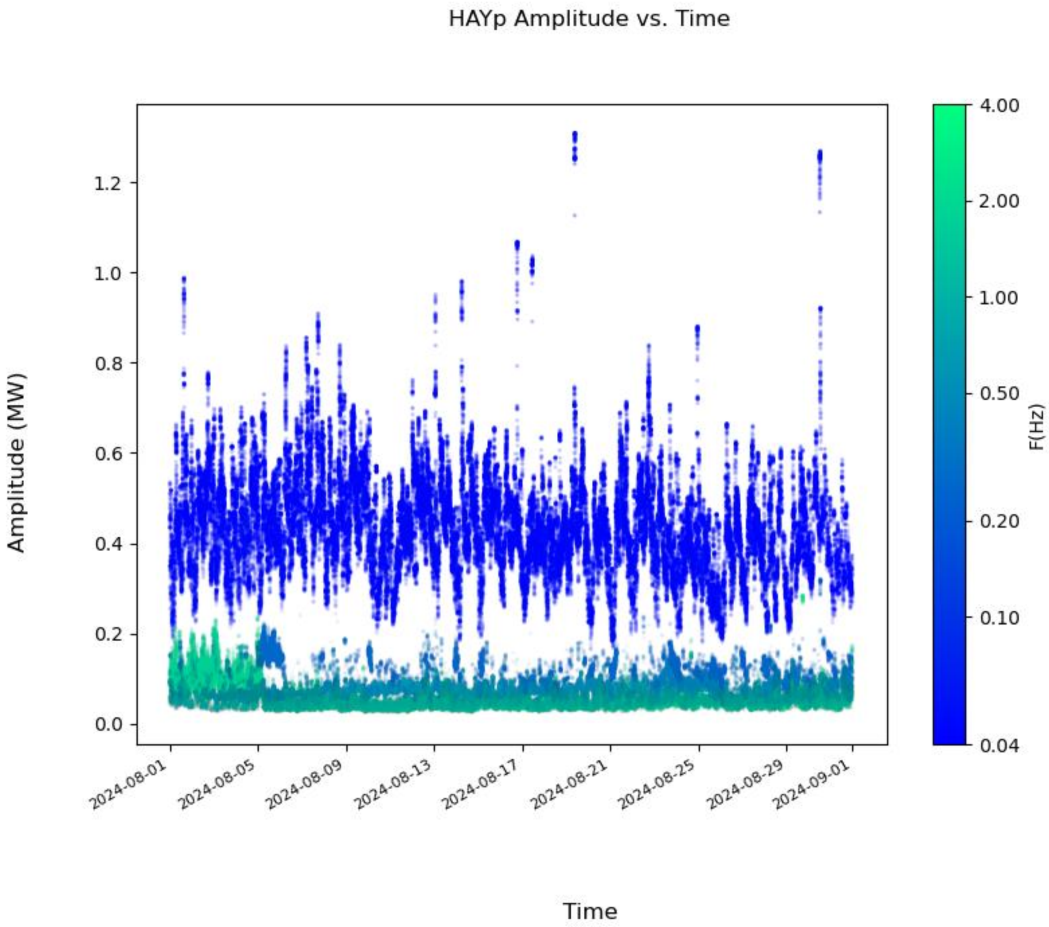


Figure 35: Haywards

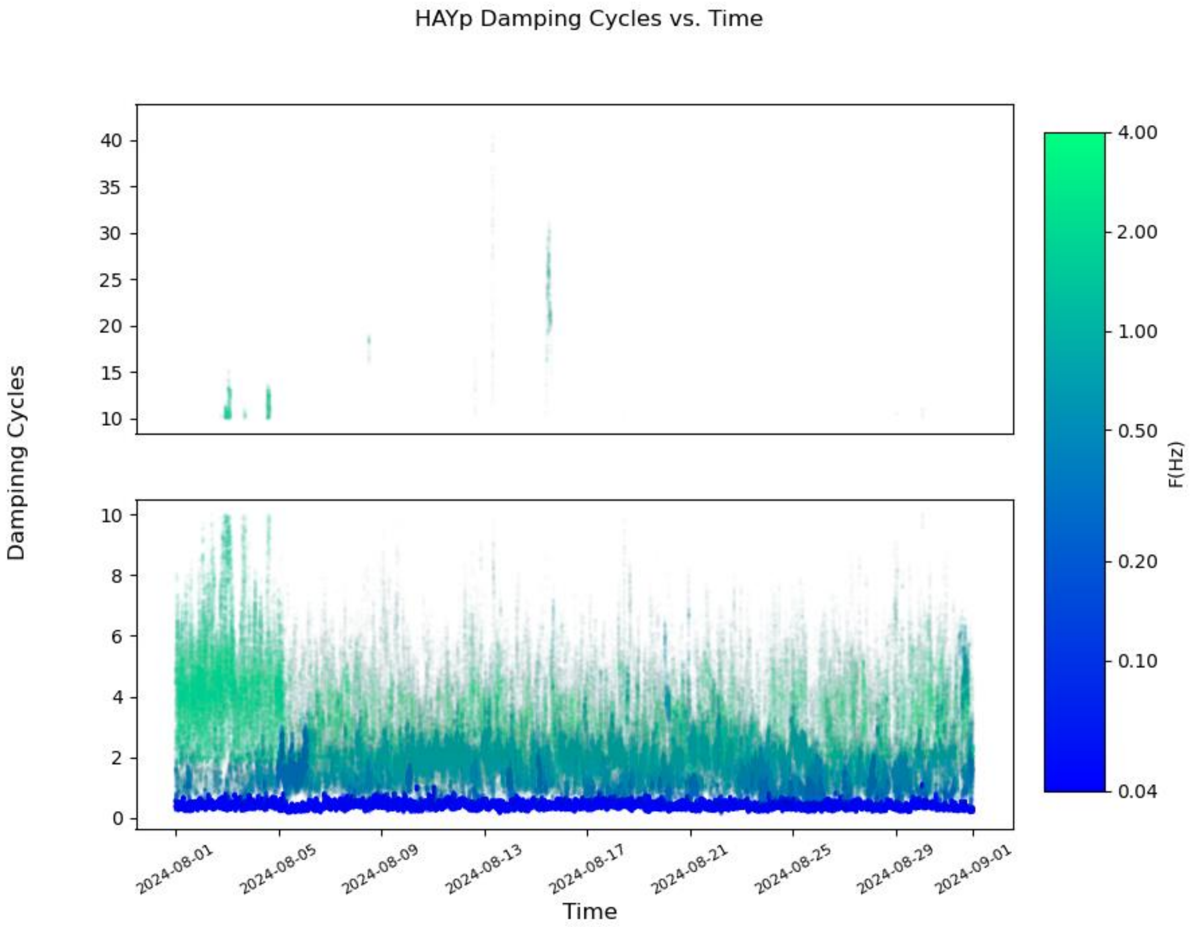


Figure 36: Haywards

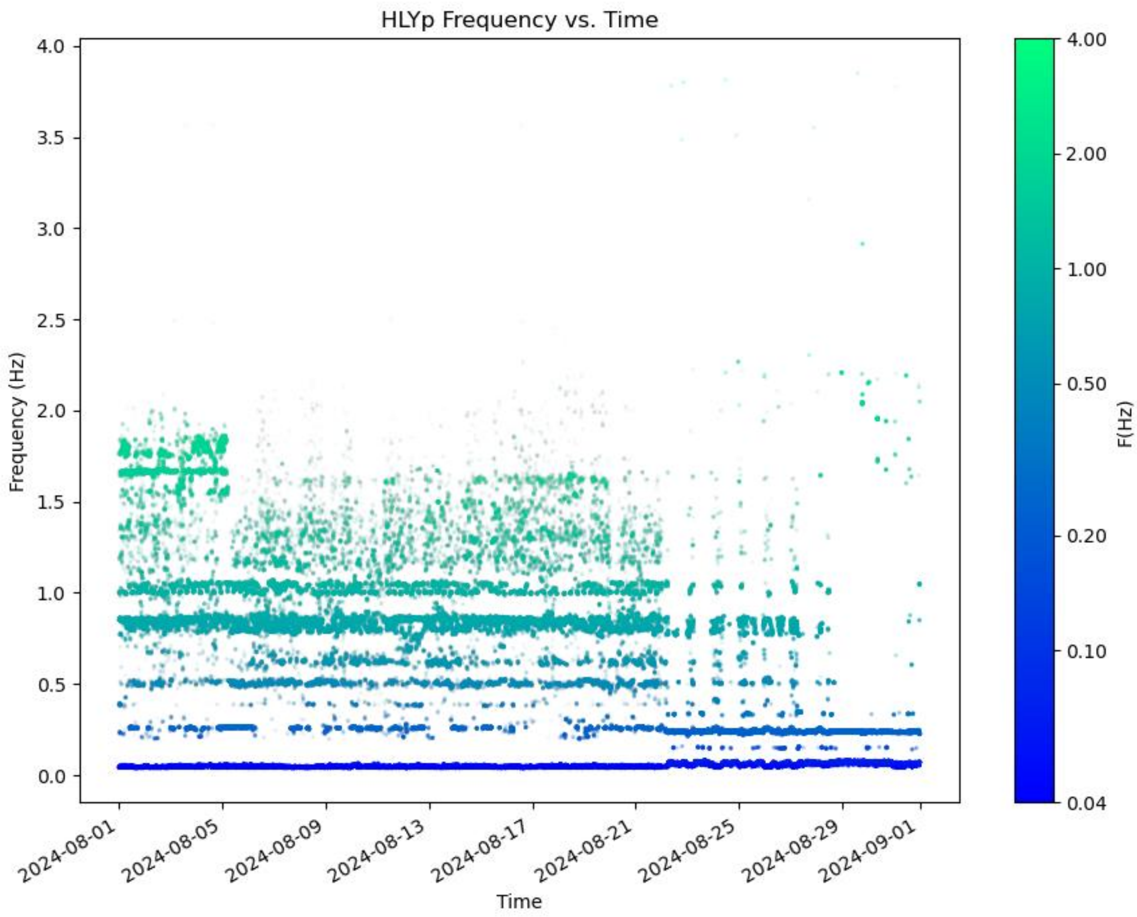


Figure 37: Huntly

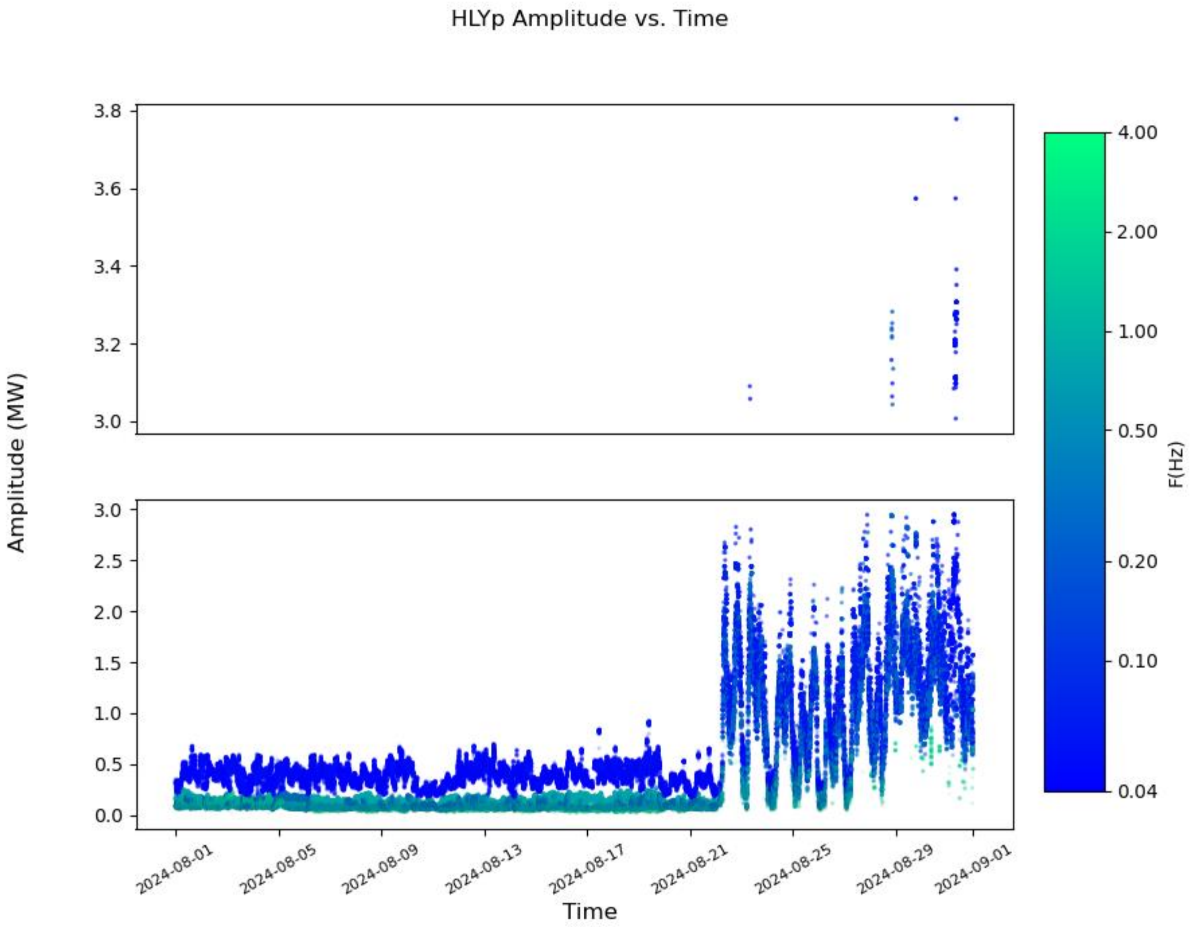


Figure 38: Huntly

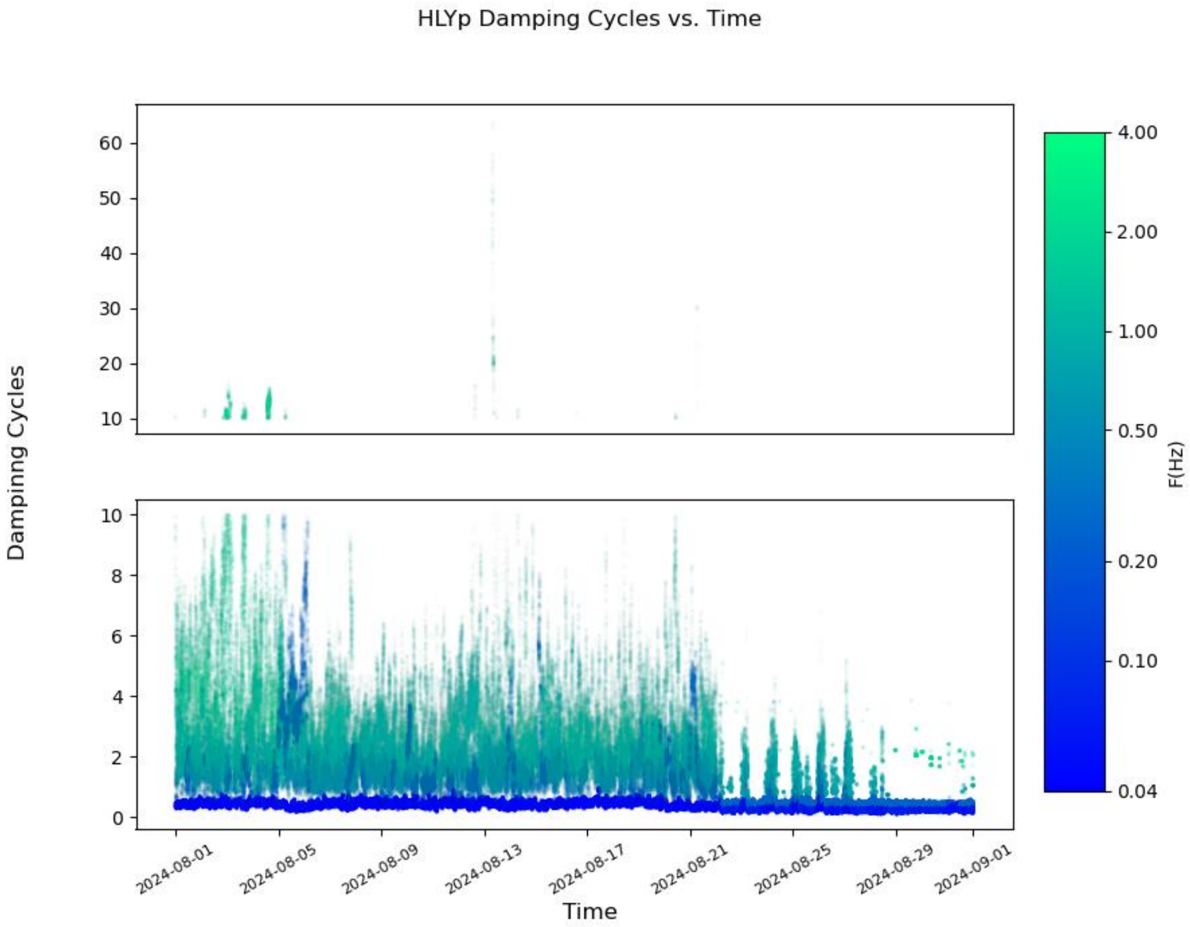


Figure 39: Huntly

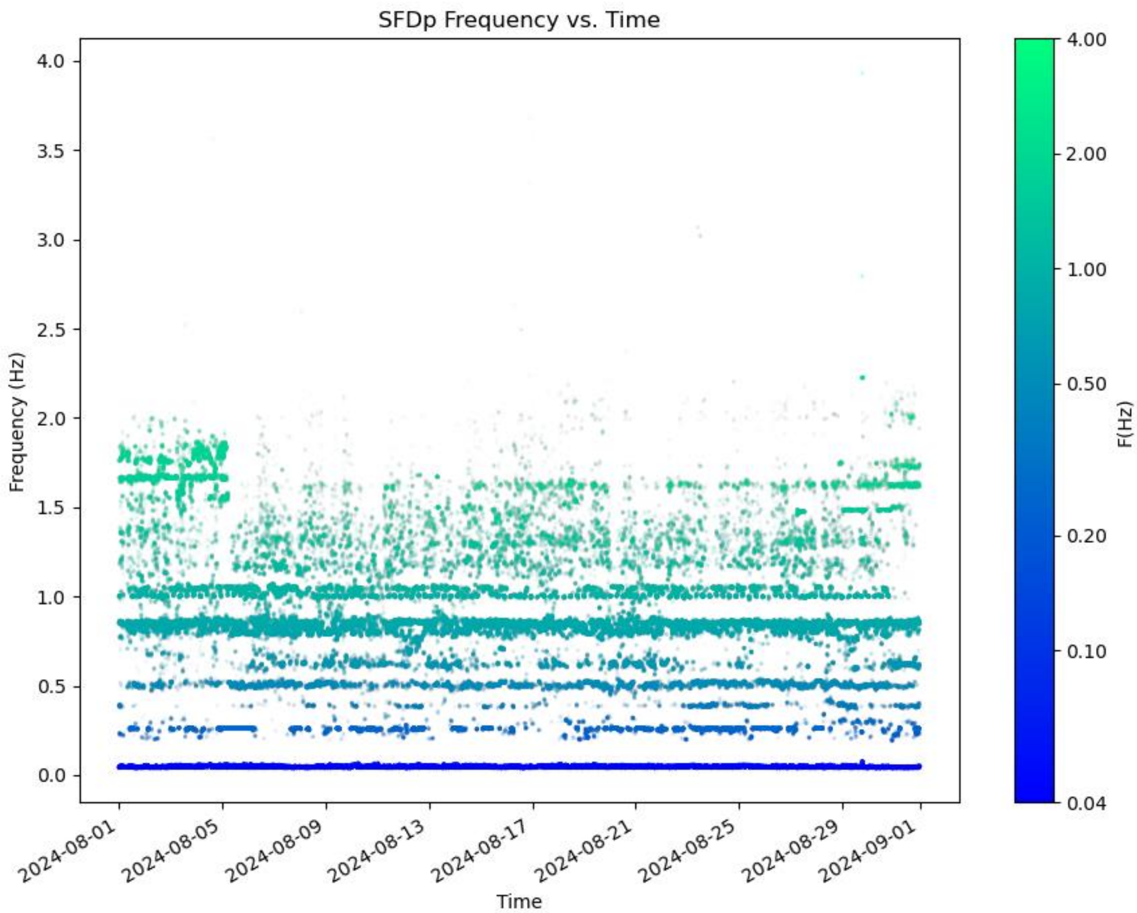


Figure 40: Stratford

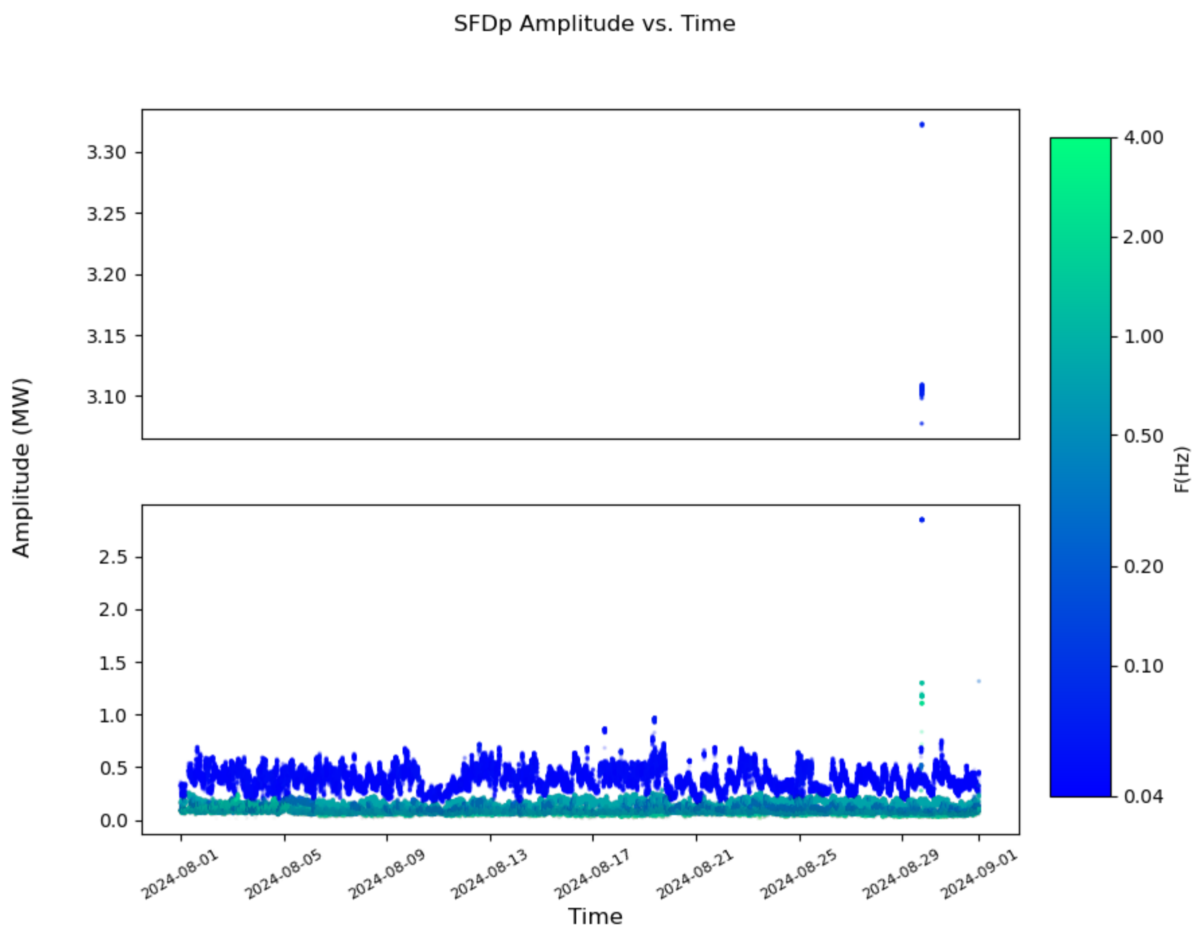


Figure 41: Stratford

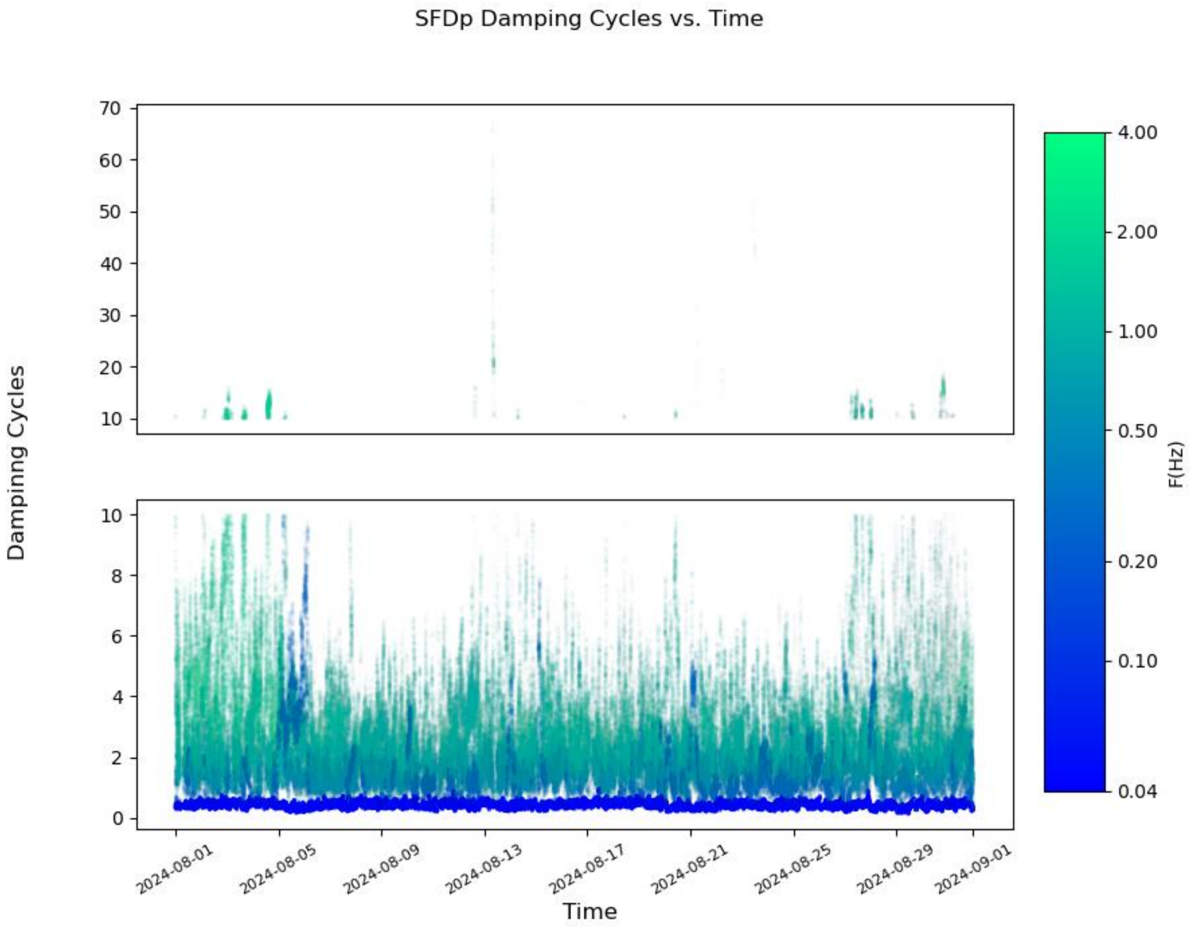


Figure 42: Stratford

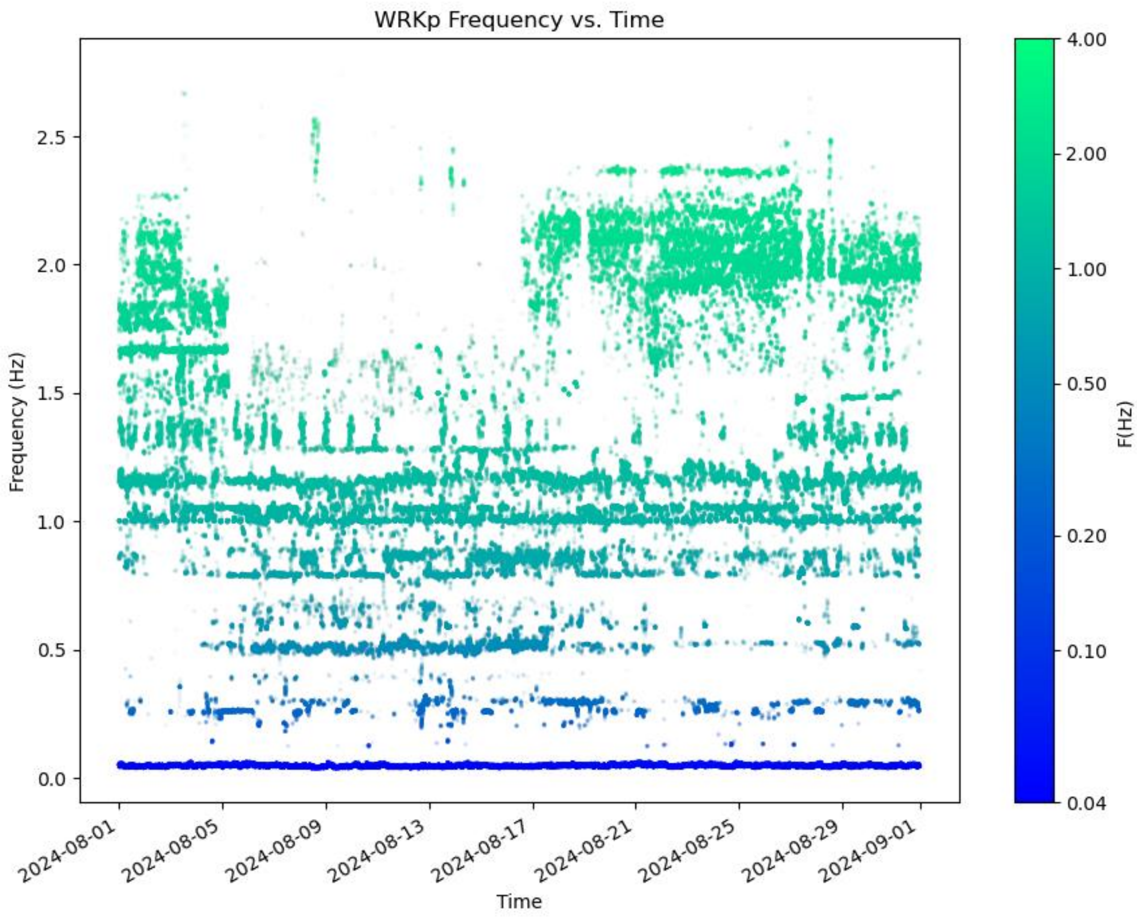


Figure 43: Wairakei

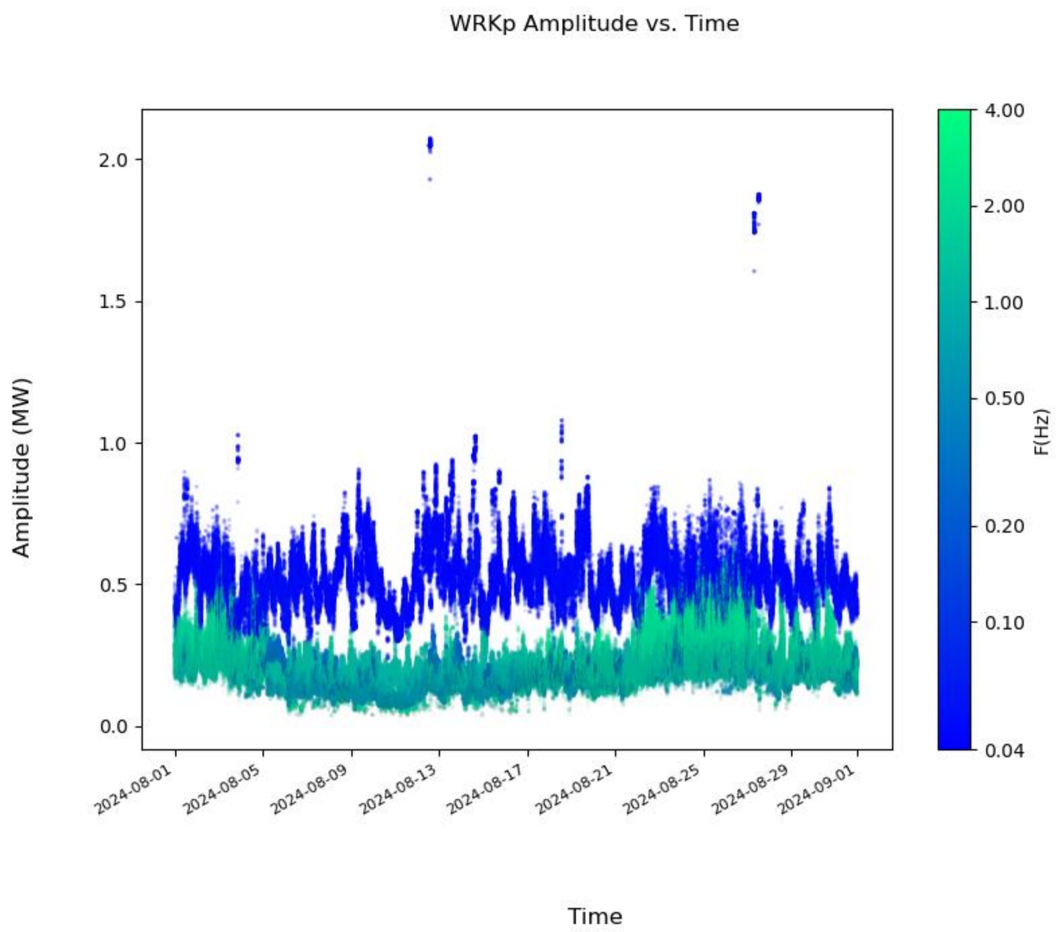


Figure 44: Wairakei

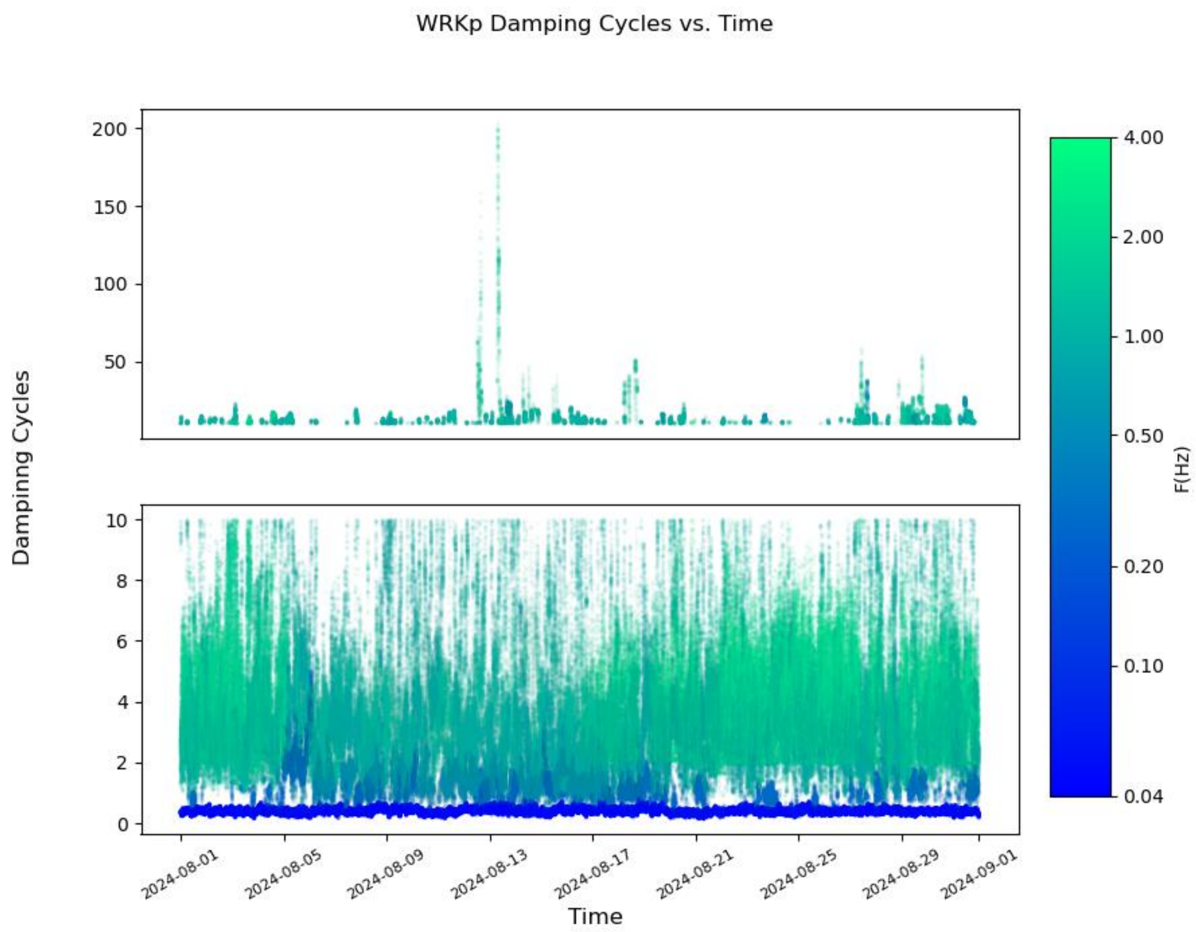


Figure 45: Wairakei

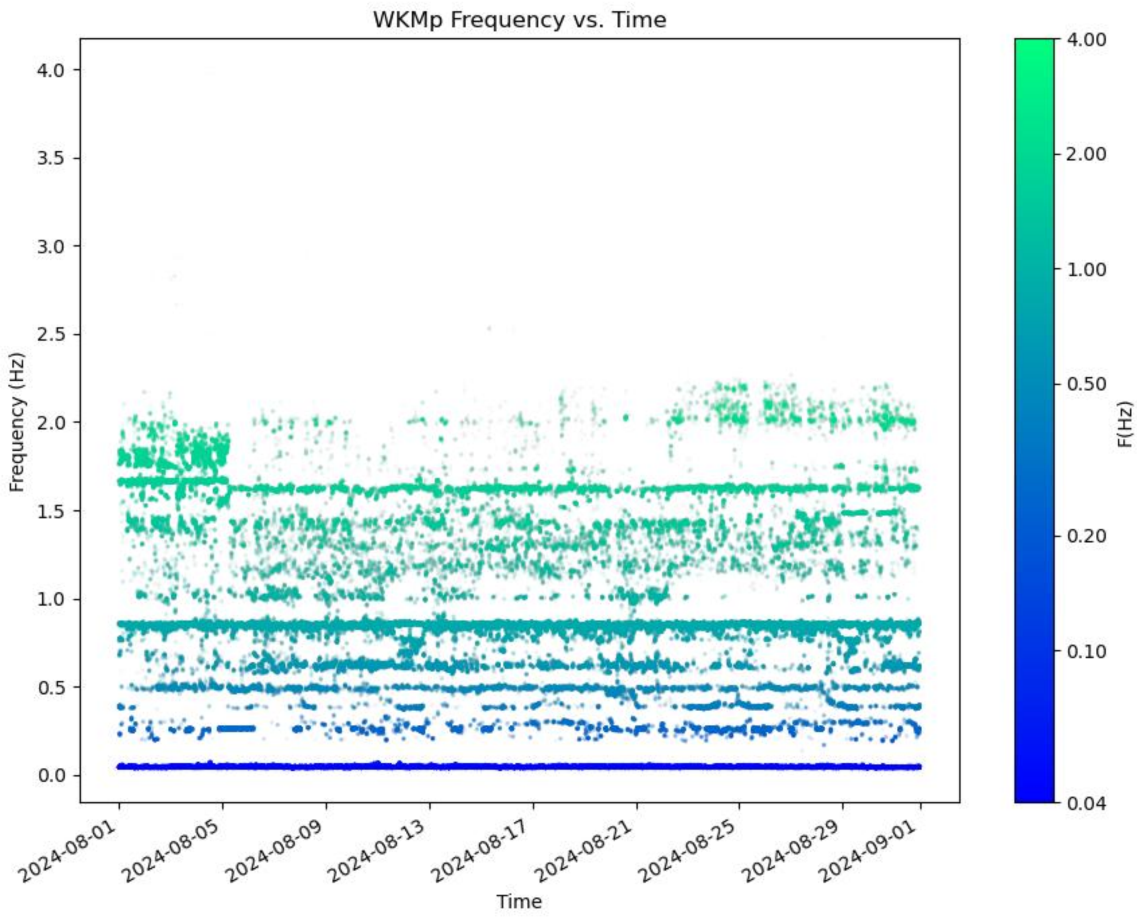


Figure 46: Whakamaru

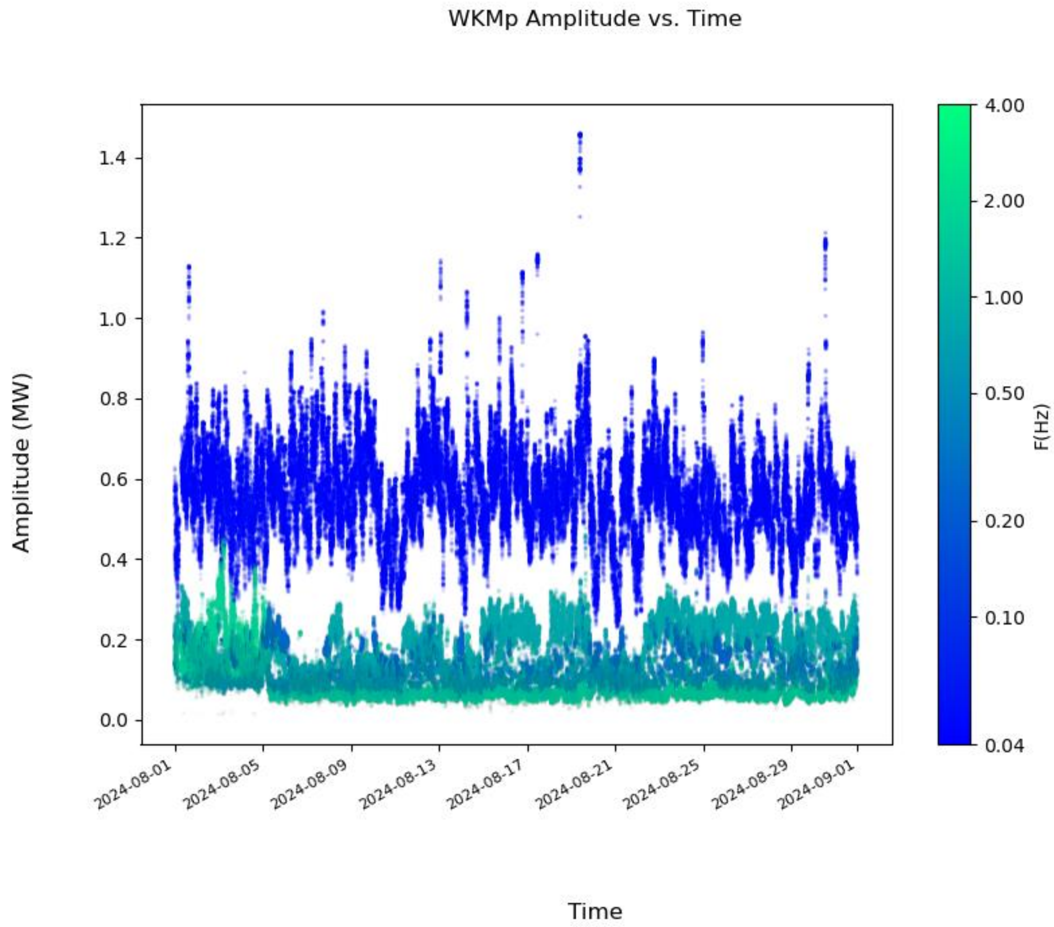


Figure 47: Whakamaru

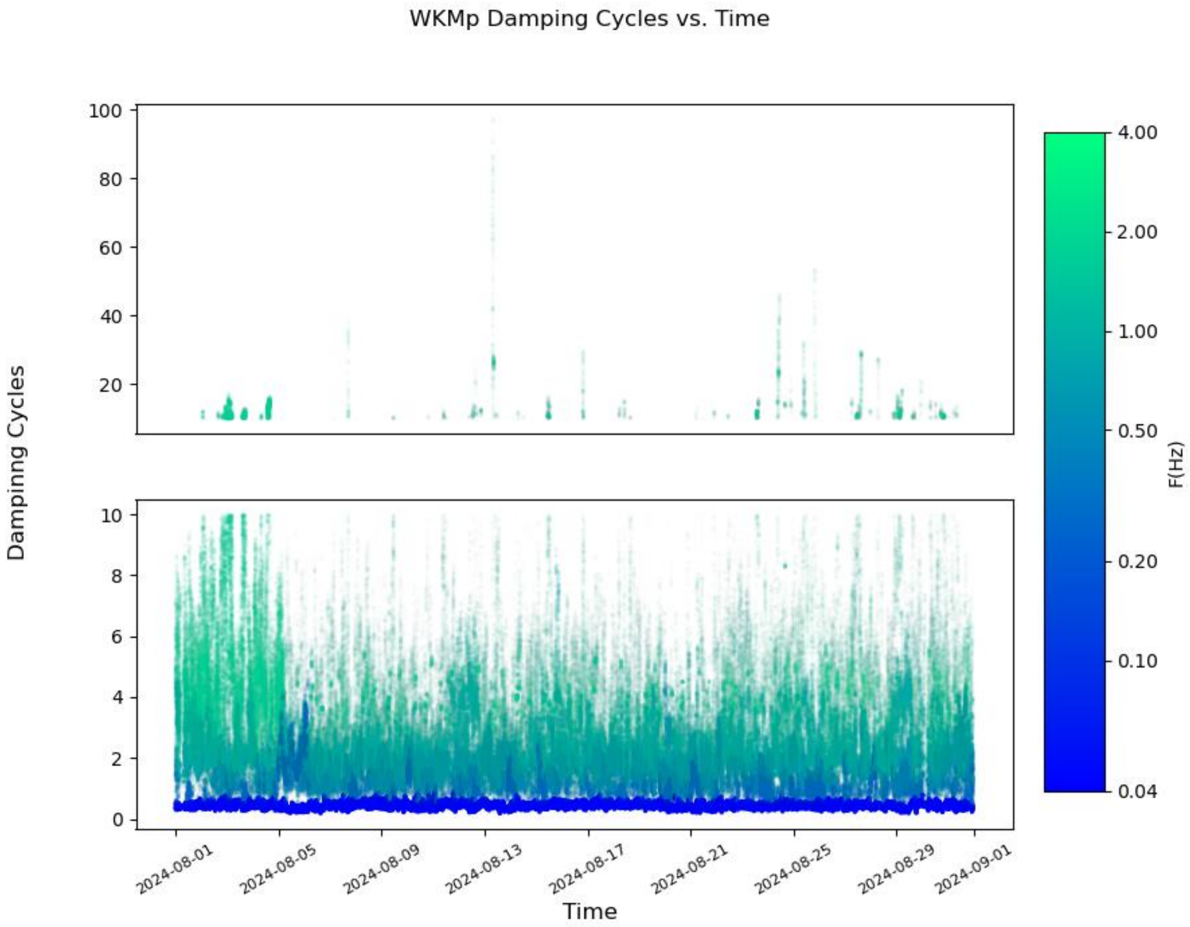


Figure 48: Whakamaru

