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Characterizing the high-frequency noise sources on a new seismological station in the southwestern region of São Paulo state

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Introduction

All seismological stations operating on Earth's surface have a characteristic seismic noise pattern. Usually, for frequencies below 1 Hz, the primary (2-10 s) and secondary microseism (10-20 s), along with the “hum” (65-500 s), are clearly visible at every station. Frequencies above 1 Hz are mainly composed of anthropogenic and environmental sources. The station Terra Rica/PR (TRCB), located in the northwestern region of Paraná state, was uninstalled due to the excessive presence of high-frequency noise. To replace TRCB, a new seismological station (MRDB) was installed at the Morro do Diabo State Park (Teodoro Sampaio/SP), located in the southwestern region of São Paulo state. The chosen location is situated approximately 7.0 km from the city of Teodoro Sampaio, 11.5 km from the main operational base of the preservation area, and 1.5 km from the nearest highway. Here, we present a first analysis of the characteristic high-frequency seismic noise of the station.

Method and/or Theory

To identify the dominant frequencies within the seismic signal recorded by the station, we calculated Probability Density Functions (PDFs) using continuous data to analyze the period-frequency spectrum. Analyzing the resulting PDFs allowed us to select a specific frequency window, and subsequently compute the Degree of Polarization (DoP) of the signal (Schimmel et al., 2003, 2004, 2011) to estimate the noise source direction. The DoP strategy was developed for characterizing microseismic noise (frequencies below 1 Hz), which is dominated by Rayleigh waves and assumes a pure retrograde particle motion (PRPM) in a vertical plane for wave propagation. However, in high-frequency noise it is harder to identify the PRPM correctly. To ensure that our analyzed signal consisted of PRPM signals only, we selected time windows with at least 90% DoP.

Results and Conclusions

Analyses of the PDFs revealed that both MRDB and TRCB exhibited high dB values for frequencies above 1 Hz (compared to other permanent stations). TRCB displayed a flatter pattern, ranging between -110 and -120 dB across the three channels, while the pattern for MRDB remained between -100 and -125 dB, with two small peaks at approximately 3 Hz and 10 Hz. For TRCB, we computed the DoP for the period between days 100 and 115 (julian, 2024). The results indicated peaks at frequencies near 2.6 Hz, 4 Hz, 7.4 Hz, and above 10 Hz. The most prominent noise sources were located south of the station (associated with identified farm infrastructure situated approximately 250m to the south), with a secondary source in the north direction (most likely the city of Terra Rica/PR, located about 8 km to the north). For MRDB, we computed the DoP for the same period, but for the year 2025. The results showed a frequency peak near 2.8 Hz and an increase of noise above 9 Hz. The 2.6 Hz peak was predominantly located in the southwest direction and is believed to be related to the nearby highway. The high values above 9 Hz were located in the northwest-southeast direction, with the most probable sources being the farms surrounding the park area and the city of Teodoro Sampaio/SP (located east of the station). In the southwest direction, corresponding to the park area, it was observed a reduced value of anthropogenic seismic noise. PDF hour analysis of noise sources indicate a reduction of the traffic in the highway, close to the MRDB station, between 23 and 6 hr everyday.

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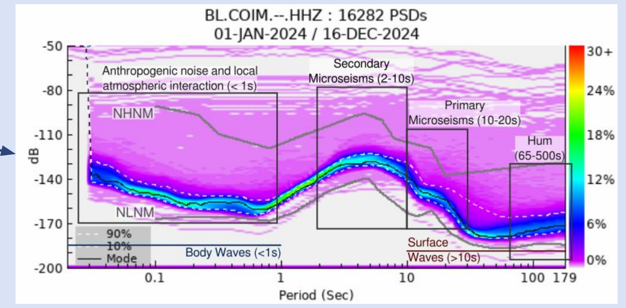
Introduction

A new seismic station (MRDB) was installed in the Southwest São Paulo state in replacement of a deteriorated one, TRCB. Station evaluation was done using Noise Probability Density Functions (PDF) and Noise Polarization attributes.

Identifying Noise Sources

PDF Analysis (McNamara et al., 2004, 2010)



Degree of elliptical Polarization (DoP) with preferred vertical plane of Rayleigh Waves (Schimmel et al., 2004, 2011)

Input:

- SAC hourly data (25sps; dt = 0.04s)

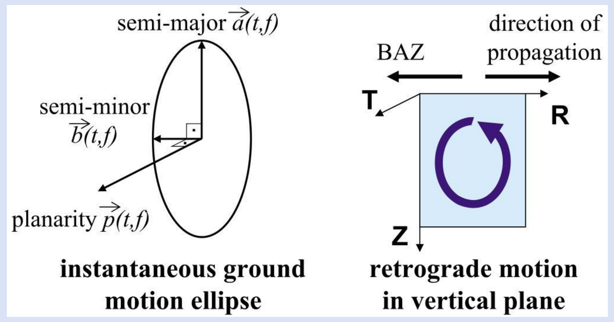
Main Parameters:

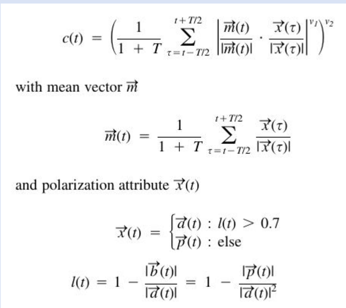
- Minimum DoP = 0.9;
- Frequency Range = 1 – 12Hz

1. S transform data into time-frequency domain

2. Eigen analysis of spectral matrices to determine the semimajor and semiminor axis of the ellipse that best defines the ground motion

3. Measure of the instantaneous Degree of Polarization (DoP) and Back-Azimuths of Rayleigh waves as function of time and frequency (*m(t)* increases for constant planarity vectors. Therefore, *c(t, f)* indicates polarization rate)





Output:

- Frequency histogram
- Azimutal polar histogram (for each selected frequency window)
- Back-Azimuths polar diagram as function of frequency

- *T(f)* ➡ small sliding data window
- *N(f)* ➡ total number of samples in each window
- v_1 , v_2 (>0) control the difference between polarized and less polarized signals (i.e. sensitivity). Usually, $v_1 = v_2 = v$
- To avoid any bias at *c(t,f)* uses unit vectors (i.e., final result does not depend on the amplitude of the signals)

	TRCB		MRDB	
	Dist [km]	Az [°]	Dist [km]	Az [°]
Terra Rica	7.7	11.9	—	—
Teodoro Sampaio	—	—	7.16	86.8
UHE Porto Primavera	48.2	316.6	74.4	274.8
UHE Taquaruçu	71.0	67.0	24.5	91.7
UHE Rosana	32.3	311.5	65.5	263.6
Atvos	—	—	20.5	42.4
Poultry Farm	0.32 – 0.48	130.8 – 200.8	—	—
SP613	—	—	1.91 – 12.74 (*1.32)	155.2 – 282.0 (*200.4)

Table 1 - Calculated distance [km] and azimuth [°] (Obspy vs 1.4.1) from TRCB and MRDB stations in relation with major anthropogenic seismic noises sources

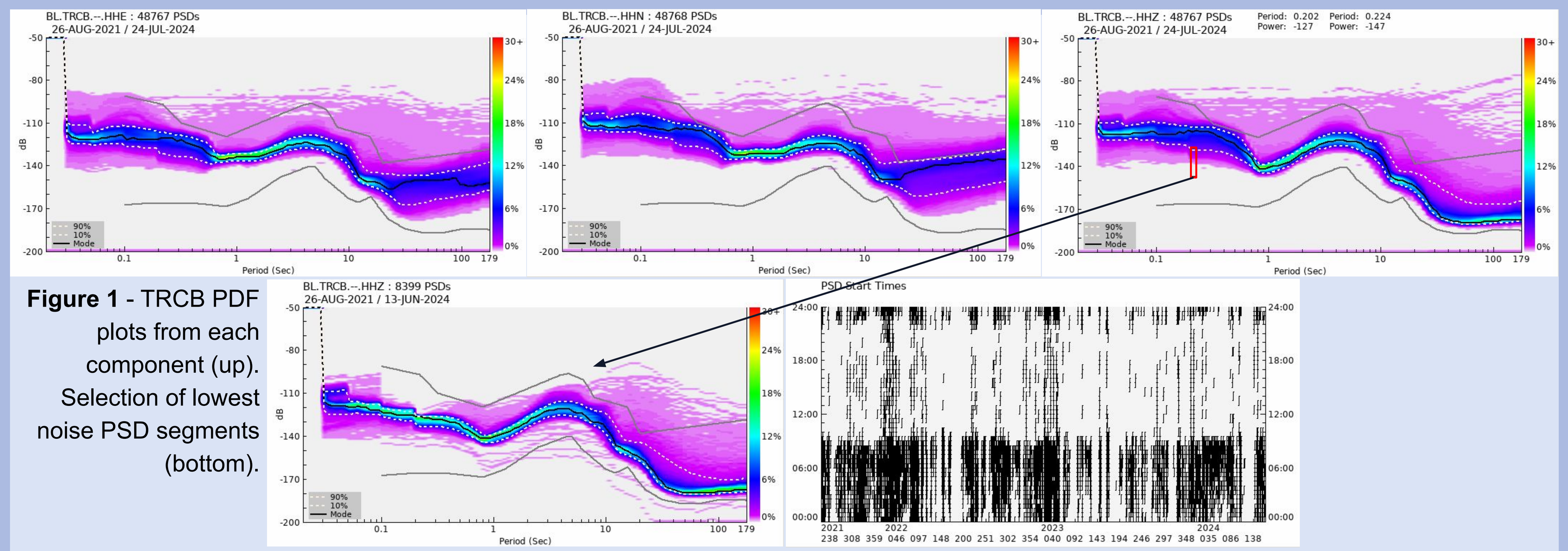


Figure 1 - TRCB PDF plots from each component (up). Selection of lowest noise PSD segments (bottom).

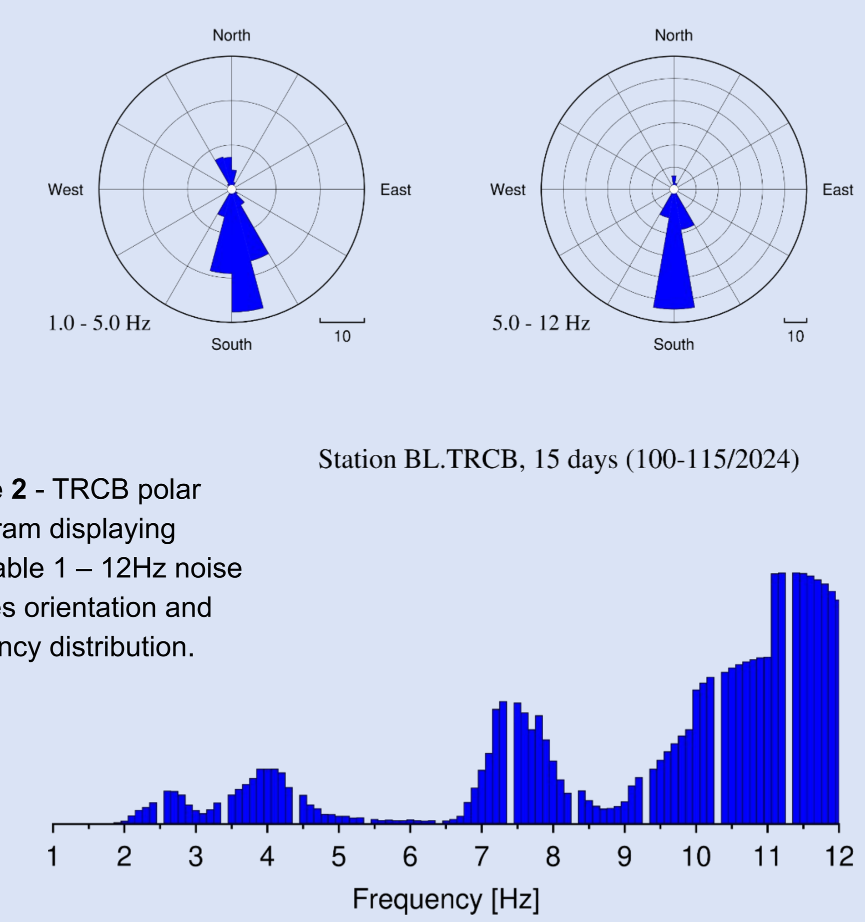


Figure 2 - TRCB polar histogram displaying preferable 1 – 12Hz noise sources orientation and frequency distribution.

Figure 3 - TRCB station

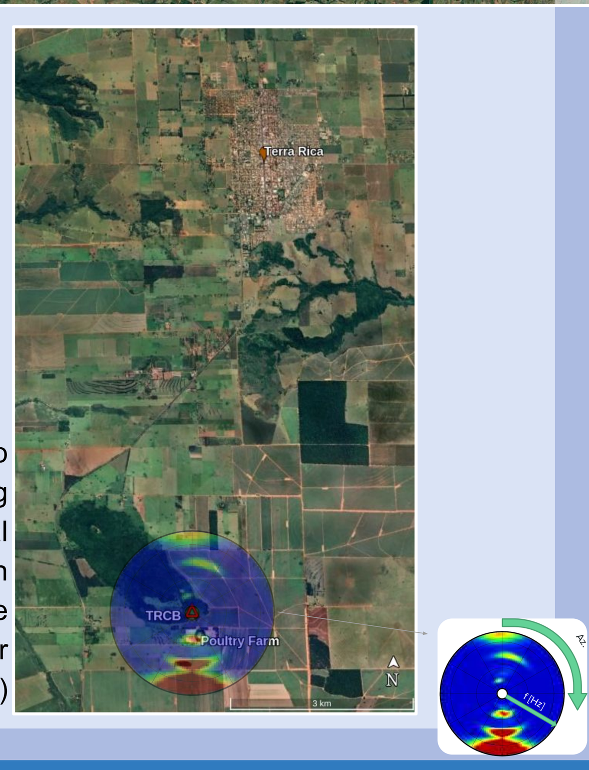
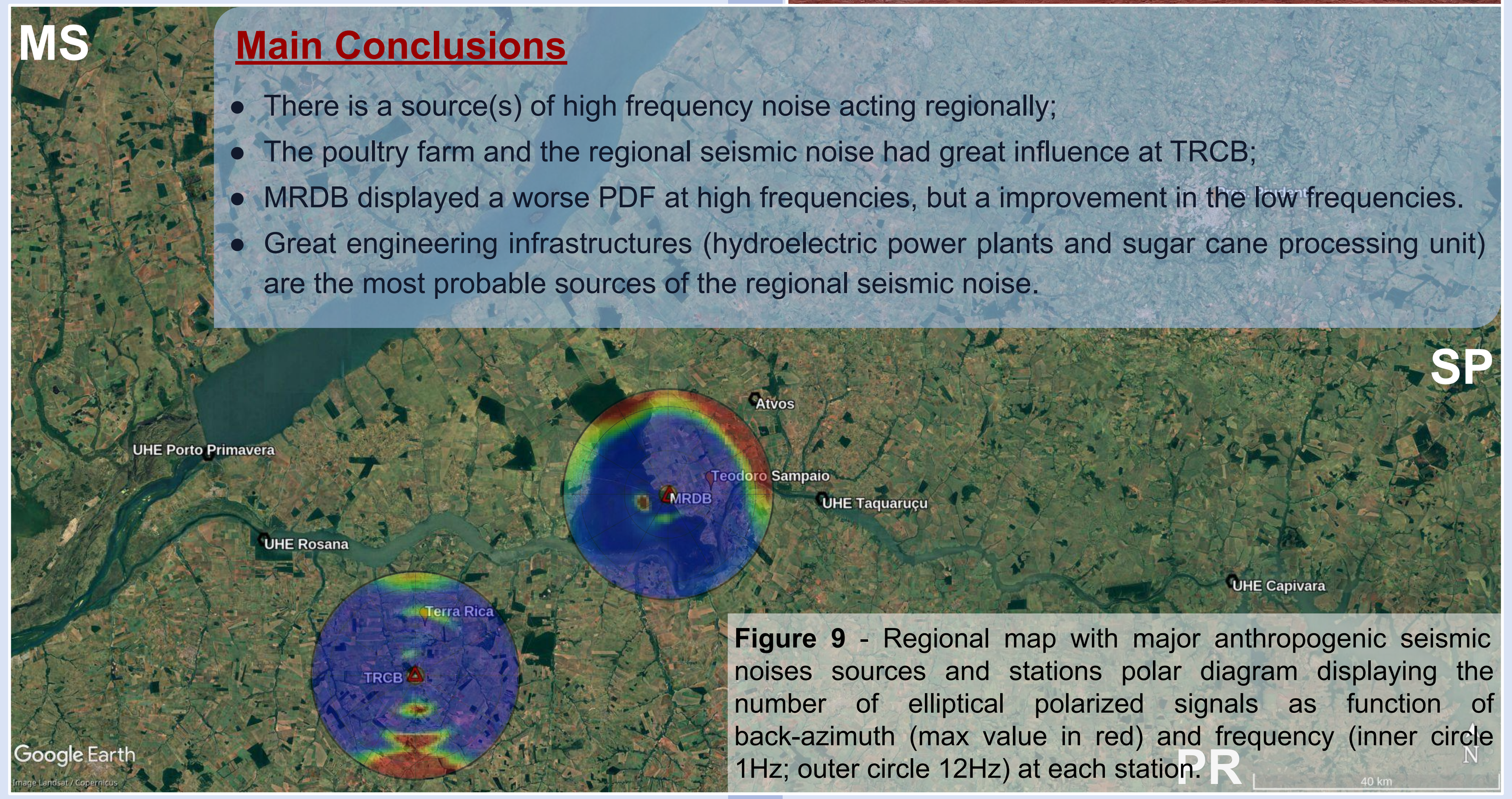


Figure 4 - TRCB local map with polar diagram displaying the number of elliptical polarized signals as function of back-azimuth (max value in red) and frequency (inner circle 1Hz; outer circle 12Hz)



Main Conclusions

- There is a source(s) of high frequency noise acting regionally;
- The poultry farm and the regional seismic noise had great influence at TRCB;
- MRDB displayed a worse PDF at high frequencies, but a improvement in the low frequencies.
- Great engineering infrastructures (hydroelectric power plants and sugar cane processing unit) are the most probable sources of the regional seismic noise.

Figure 9 - Regional map with major anthropogenic seismic noises sources and stations polar diagram displaying the number of elliptical polarized signals as function of back-azimuth (max value in red) and frequency (inner circle 1Hz; outer circle 12Hz) at each station.

Figure 8 - MRDB station

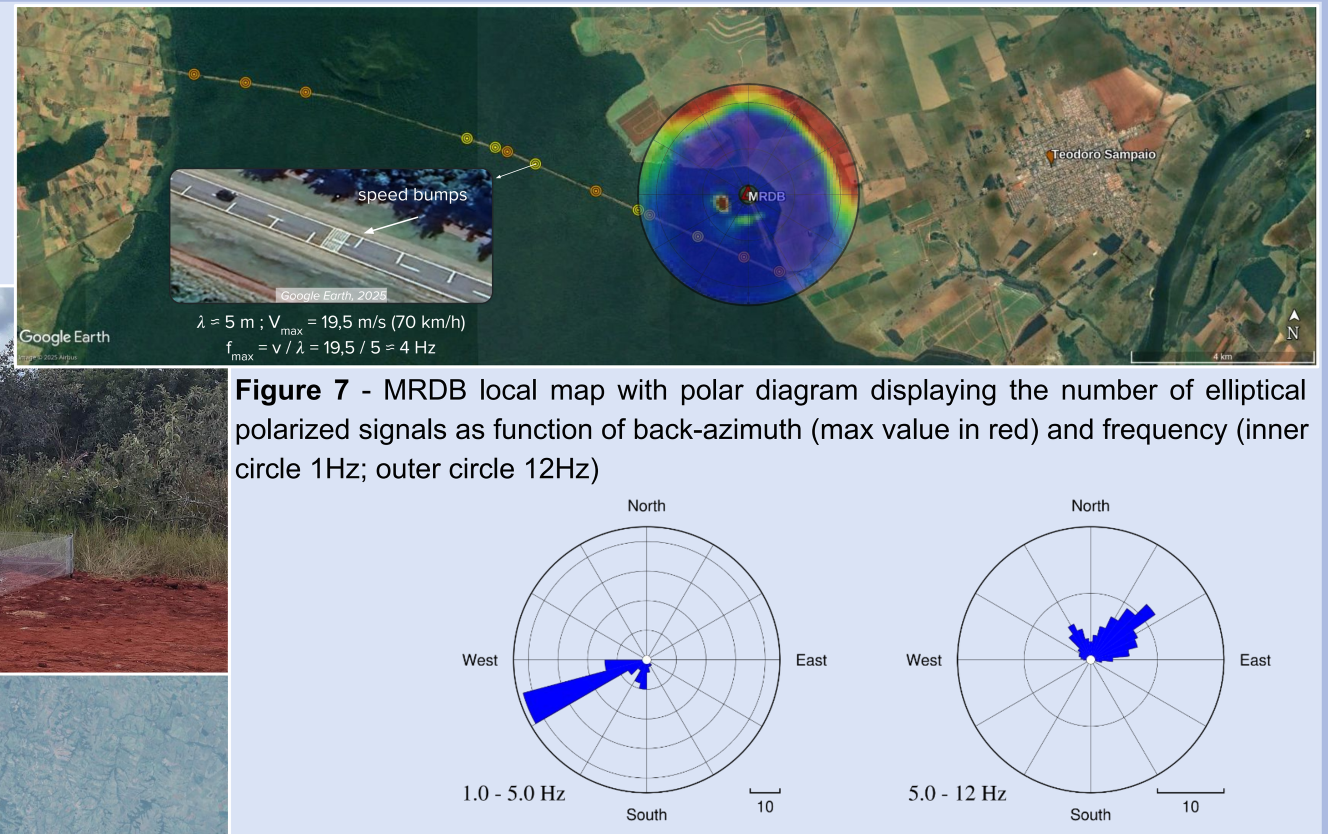


Figure 7 - MRDB local map with polar diagram displaying the number of elliptical polarized signals as function of back-azimuth (max value in red) and frequency (inner circle 1Hz; outer circle 12Hz)

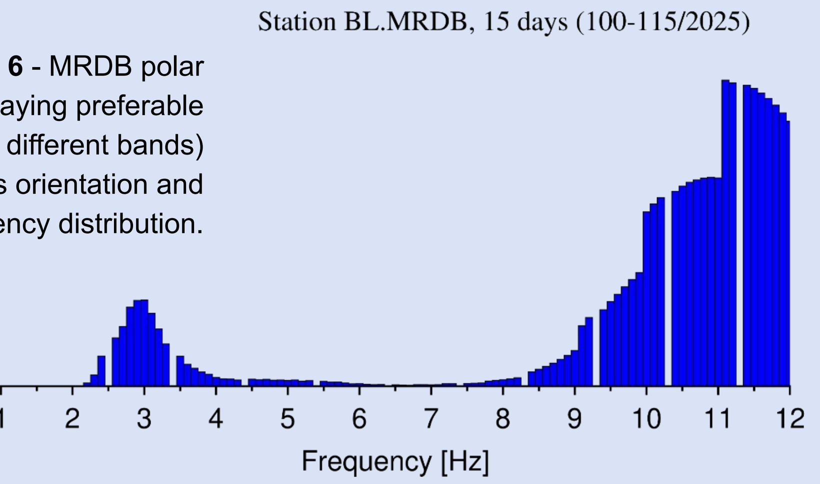


Figure 6 - MRDB polar histogram displaying preferable 1 – 12Hz (in 2 different bands) noise sources orientation and frequency distribution.

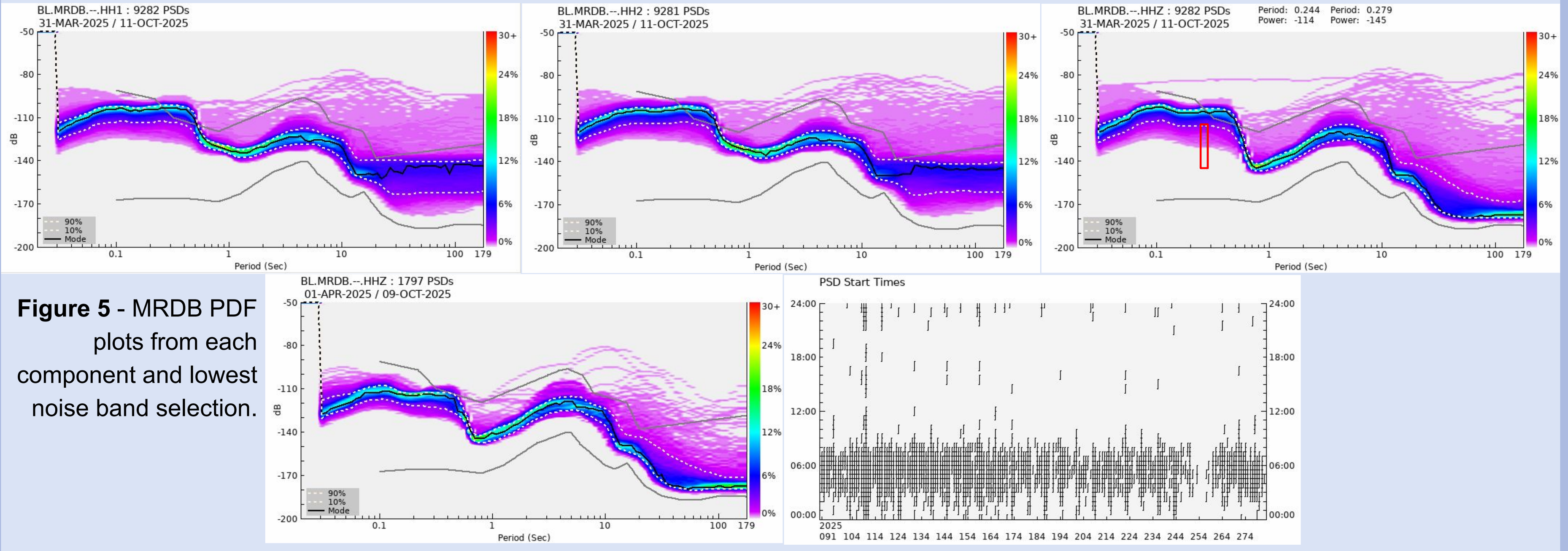


Figure 5 - MRDB PDF plots from each component and lowest noise band selection.

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