

Investigating a Mysterious Infrasound Signal Using Template Matching

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Introduction

- Infrasound - sound with frequencies below human hearing - come from various sources including meteor strikes, earthquakes, and atmospheric disturbances. A mysterious infrasound signal was recorded in Riverwoods, IL; Residents reported a loud boom and possibly bright lights in the sky.
- Aim:** Detect events similar to mysterious signal using template matching and analyze temporal & spectral features to identify possible sources.
- Challenges:** High background noise and few reliable sources to verify the local environmental conditions during event duration.

Methods

We developed a template and cross-correlated it with continuous data (2022–2024) from station L44A at Ryerson Woods, Lake County Forest Preserve, IL [4] to identify matches.

Template Creation & Data Pre-Processing

- The main signal of the mysterious event was 20 minutes (3:15-3:35 UTC) in duration. We created a 1-hour template with the main signal and 20 minutes before and after the signal.
- Data was detrended, cosine-tapered (max percentage = 0.05), and low-pass filtered (<0.01 Hz) using a 4th order Butterworth Low-pass Filter.
- 24-hour data from 2022-2024 was cosine-tapered (max percentage = 0.001), and filtered same as template.

Cross-Correlation Algorithm

- Used Obspy correlate template() to cross-correlate the raw data against our template via FFT, normalizing results.
- Matches required correlation >0.35 (threshold validated via visual inspection, using 02/23–03/23 data).
- If matches were <10 min apart, only highest cross-correlation was kept; otherwise, it recorded separately.

Identifying Possible Sources

- Low frequencies (<0.01 Hz) suggested Meteors, Space Debris, Thunder, or Storm/Wind fluctuations.
- No match with thunder based on well-defined infrasound signals.
- Template duration (~20 min) exceeded typical meteor/debris signals.
- Most matches correlated with high precipitation and wind speeds.
- Storms/Wind as a Likely Source**
- Using NOAA data [5], precipitation data was gathered by a nearby station (<6km), while other weather statistics were gathered from a station about 10 km away.
- We compared the weather statistics during dates with signal matches with average weather statistics
- Potentially significant variables: Precipitation, Fastest 2-min Wind Speed, Thunder and Fog Presence.

Discussion

Template matching gives similar events, but the rarity, long signal length, and low frequency range suggest this is an unusual infrasound event.

Primary Sources

- No relevant atmospheric events reported locally or in the greater county area on dates with similar signals.
- Unreliable accounts on the event's duration and reports of sounds and light conflicting whether it was caused by a meteor or storm.

Template Matching Analysis

- The signal's shape, length, and frequencies points to a few sources, namely meteors, space debris, thunder, and storm/wind fluctuations.
- Signal features are similar to infrasound events caused by storm or wind events.
- Meteorological data correlates large storm features with event dates but remains inconclusive.

Moving Forward

- While the mysterious signal remains mysterious, our research demonstrates how template matching helps narrow down possible sources and identify similar events in the area one would have otherwise been unable to see.
- Template matching proves valuable for detecting/classifying infrasound events, motivating improvements in future detection algorithms.

Results

Figure 1: Raw hour-long template stream, with cleaned version below.

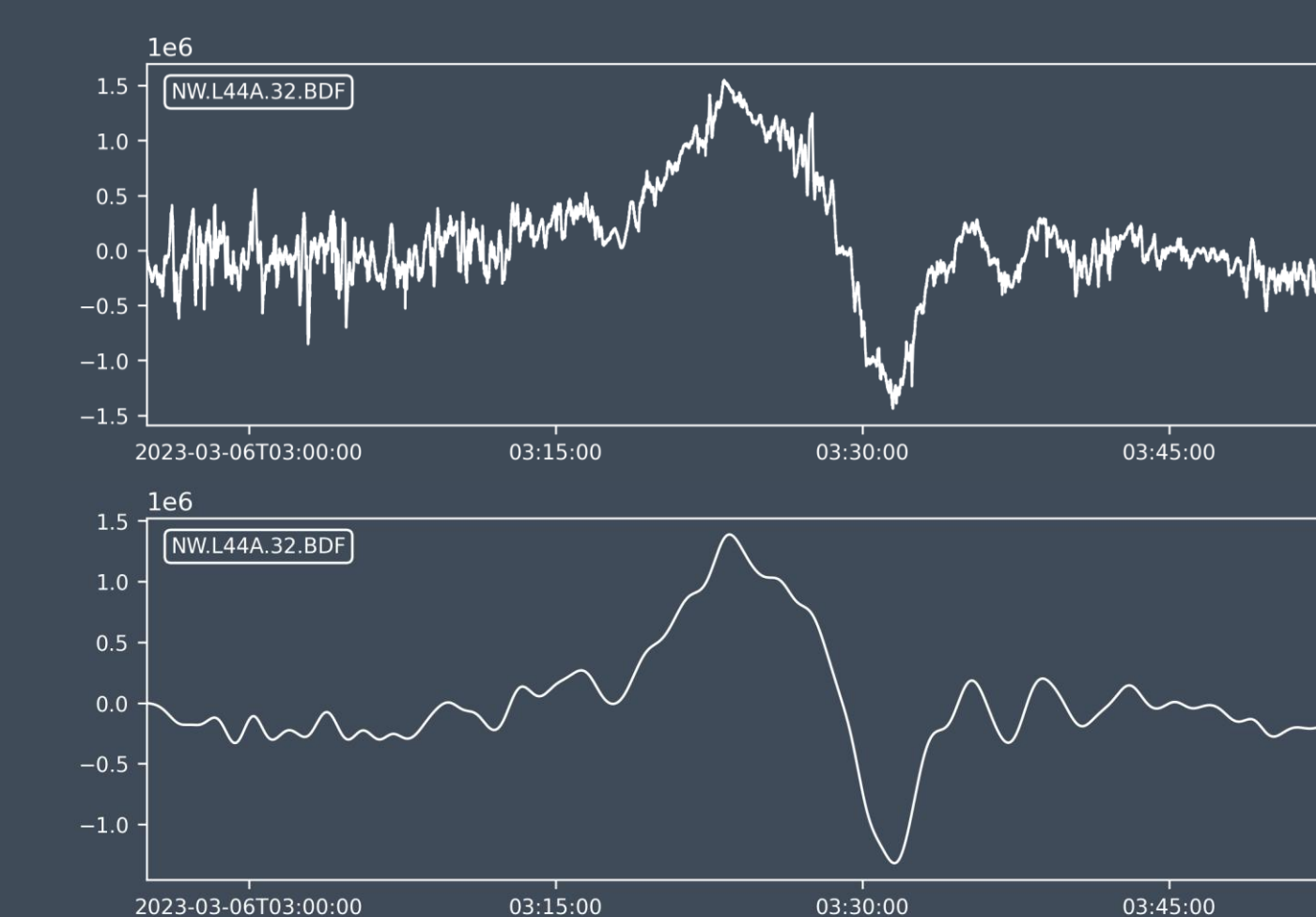


Figure 2: Amplitude vs. Frequency plot of raw template data used to determine frequency filtering.

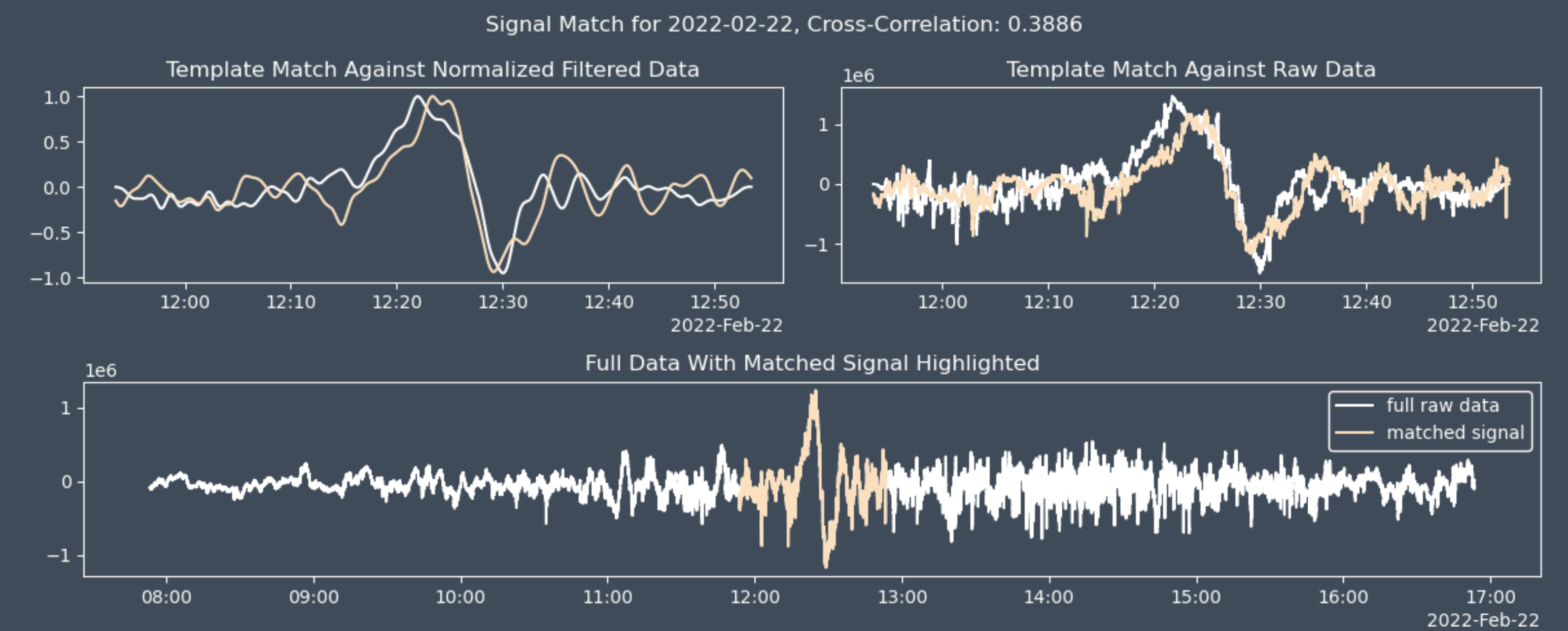
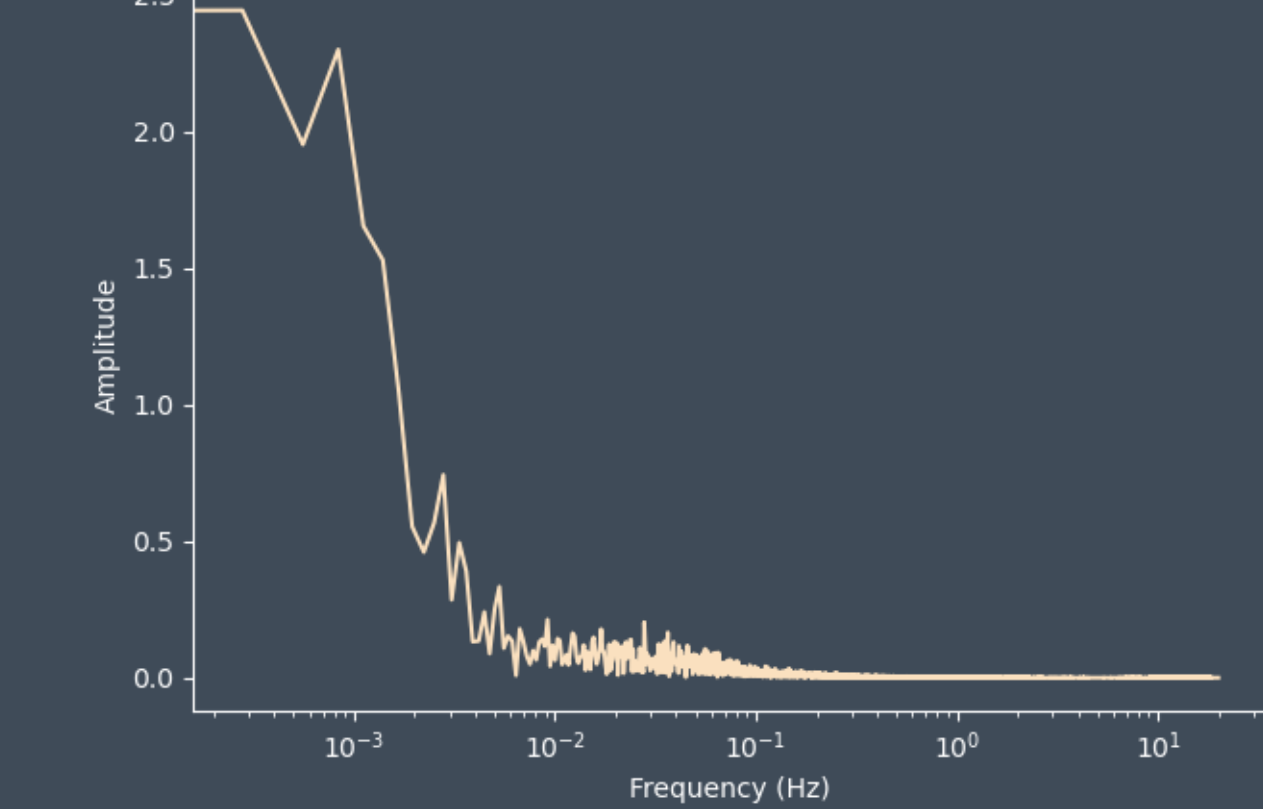


Figure 3: Example of one of the signal matches found from cross-correlation against template. Comparison against the template is shown on top, while the bottom showcases the signal in context of the raw data stream around it.

Date/Time (CT)	Correlation Values
2/22/22, 6:20 AM	0.3886 (Strong Match Visually)
5/19/22, 4:45 AM	0.3696
7/15/22, 5:10 PM	0.4810
7/23/22, 5:00 AM	0.4538 (Strong Match Visually)
1/18/23, 8:10 PM	0.3821
5/7/24, 8:50 AM	0.4642
5/20/24, 12:10 PM	0.3955 (Strong Match Visually)

Table 1: All 7 matches found, along with correlation values and a short note if the match corresponds to the template well visually.

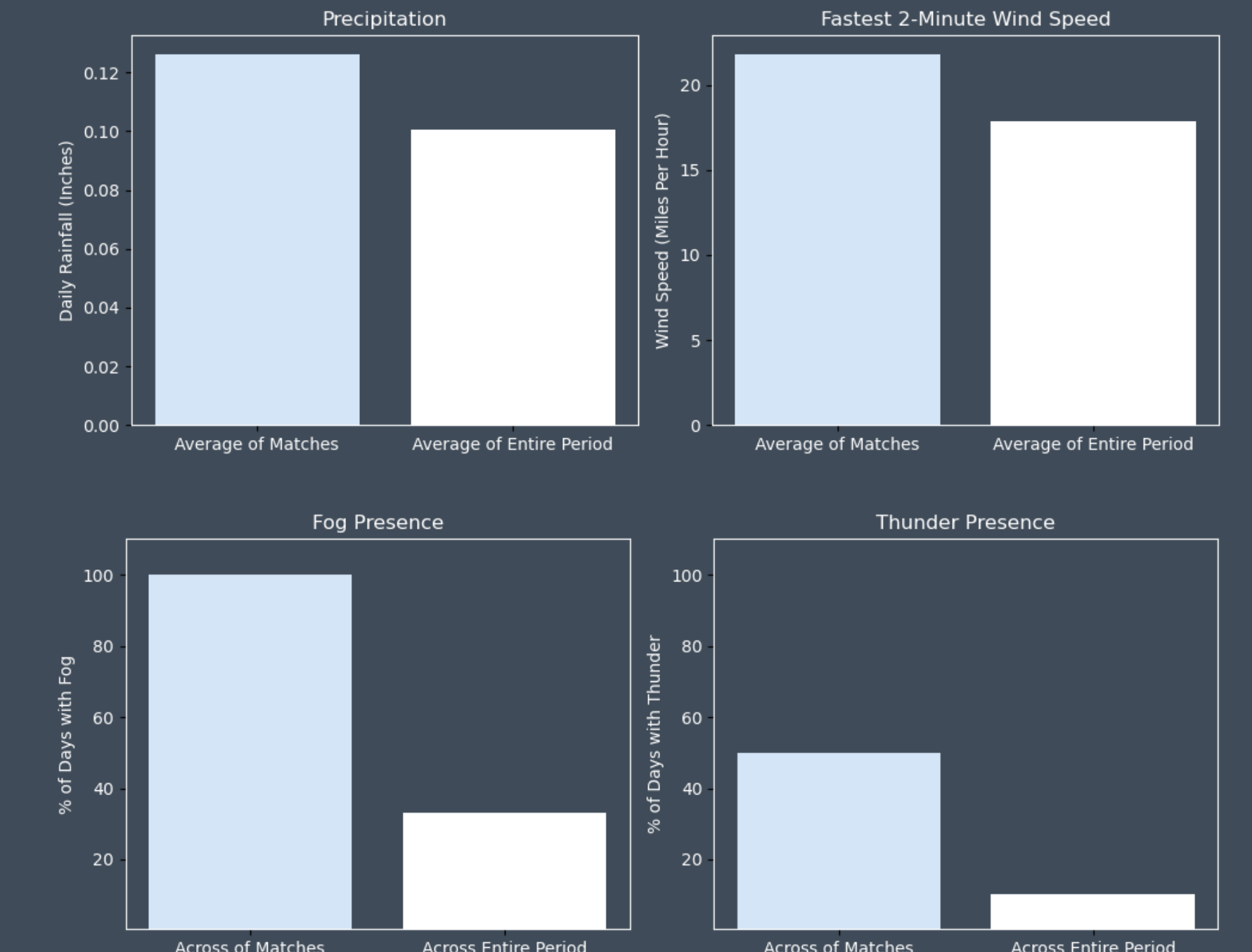


Figure 4: Average of dates with matches compared to average across two-year period across four weather patterns

Source	Frequency (Hz)	Notes
Meteor	0.01–20	Typically lasts only seconds
Space Debris	~0.1–10	Typically lasts only seconds
Lightning	0.5 - 20	Signals from discharges do not match shape
Storm/Wind	~0.02 - 20	Microbaroms (0.12 – 0.25 Hz), Convection Storms (0.02 – 0.20 Hz), but not Tornadoes (1 – 20 Hz)

Table 2: Typical frequencies of possible infrasound sources, along with research notes to help rule out possibilities. [1][2][3]

References

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