# Seismic Monitoring of the Temporal Changes of the Red Cedar River

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## BACKGROUND

- Heavy rain and snowmelt increase the **discharge rate** of the **Red Cedar River**
- **Flooding** at MSU during increased river discharge makes getting around campus difficult
- Increased discharge of river flow increases force on the river bed, generating seismically detectable signals.

## OBJECTIVES

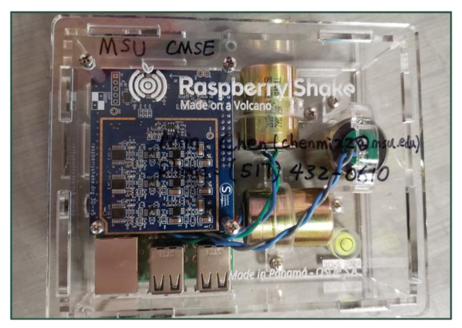
Our main goal was to **monitor the discharge rates** of the Red Cedar River through **seismic signals** recorded outside the channel close to the river. To do this we needed to:

- Deploy seismometer outside river channel
- Perform seismic data analysis using **spectral analysis** of time series data
- Find correlation between change in power of seismic signals and undulation of river discharge

## METHODS

**Raspberry Shake 3D:**

- Records frequencies from .7-40 Hz
- Continuously records and streams data to server



**Fast Fourier Transform (FFT):**

Time series data in temporal domain → Time window of data in frequency domain

**Power Spectral Density (PSD):**

Calculation of the energy distribution of energy for each frequency. PSD is normalized with a baseline PSD to reflect increase in PSD.

## RESULTS

### Comparison Between Weekend and Weekday Signals

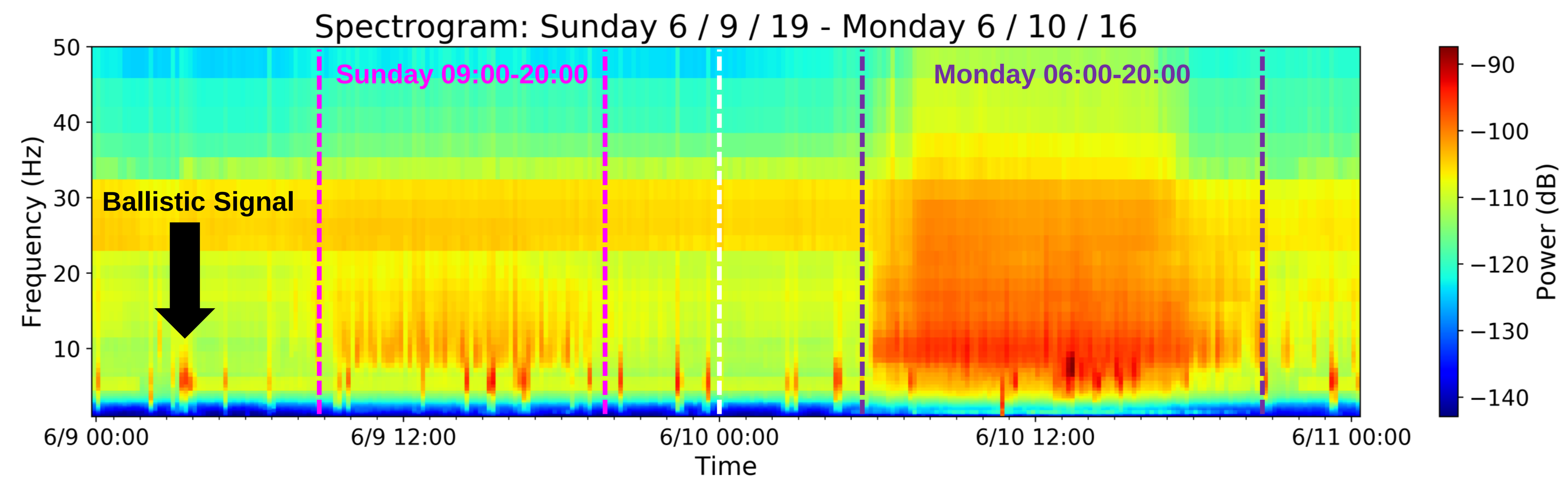



**FIGURE 1:** This spectrogram illustrates the increase in human activity from the weekend to the work week. A wider range of signals at higher amplitudes are produced on Monday June 10th than signals recorded on Sunday June 9th, especially in the 5-20 Hz range. Sporadic ballistic signals are also recorded, which are likely signals from passing trains and construction activity.

### Probability Density Function for PSD

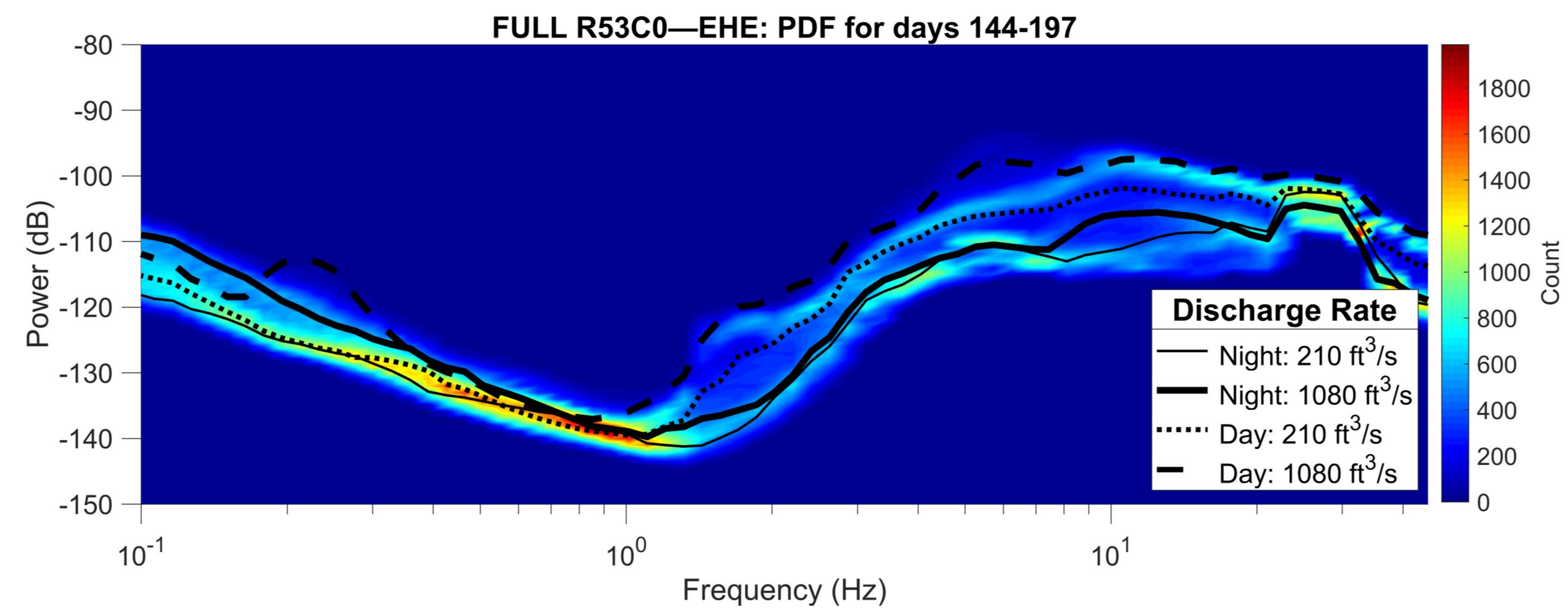



**FIGURE 2:** Probability Density Function for the East Component Power Spectral Densities. Solid lines represent PSDs at different discharge rates during nighttime and the dotted lines during the day. There's an overall increase in PSD during the day over all frequencies but only an increase at night from approximately 7-20 Hz.

### Differential Spectrogram

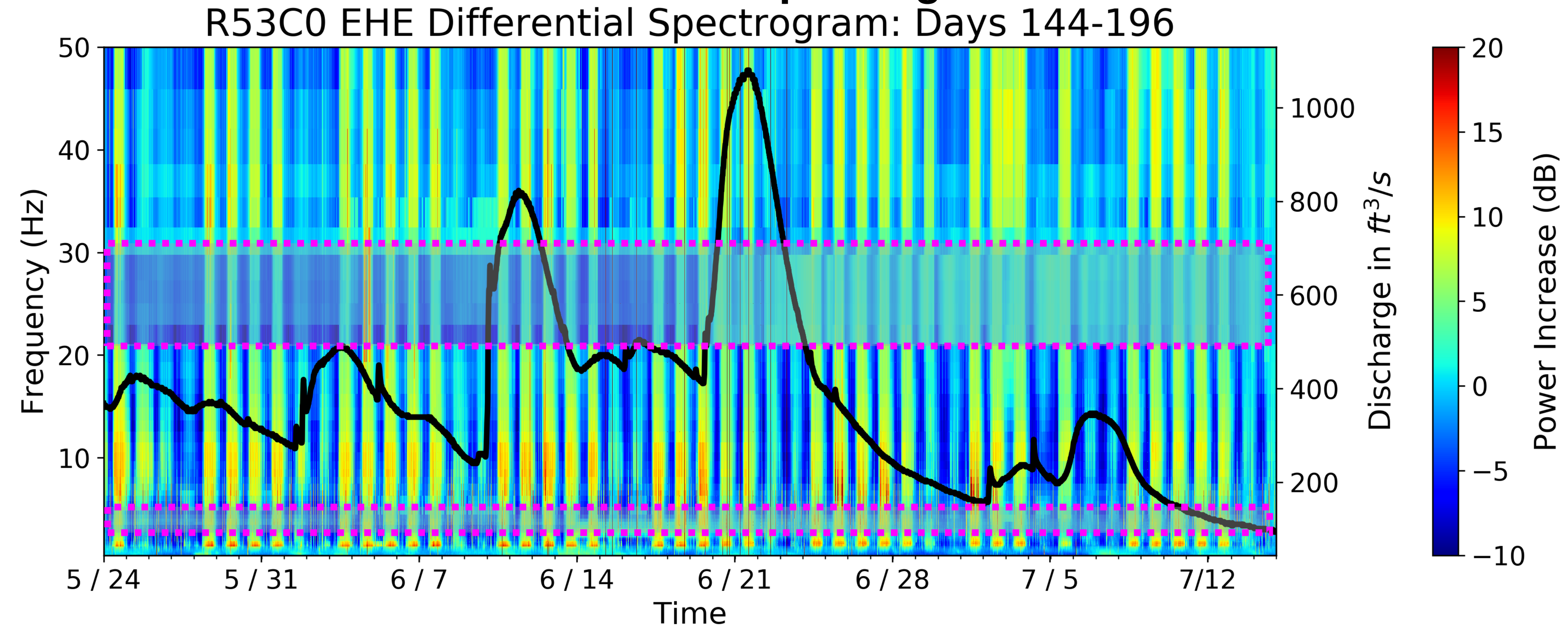



**FIGURE 3:** Differential Spectrogram created from PSD calculations for 20 min time windows with a 50% overlap. Baseline PSD created from normalizing median PSD under a 135 cubic feet per second threshold. Daily variance in PSD increase is extremely high and dominates most frequency ranges. There is no obvious correlation between discharge data[3] and PSD increase. Frequency ranges outlined in magenta (1-3 Hz and 21-31 Hz) appear to be less affected by daily PSD increase and may be better ranges for further river signal exploration.

## CONCLUSION

There is no recognizable increase in Power Spectral Density related to the increase in discharge rates in the Red Cedar River. This could be explained by:

- Seismic noise generated anthropogenically (e.g. construction, traffic) **drowning out** river signals
- Raspberry Shake 3D needed to be **stored indoors**, which increased data noise
- Time period of collected data (May 24th to July 16th ) was **short** and discharge fluctuation was **minimal**

**Future Investigation:**

- **Cross-correlate** seismic data to minimize random anthropogenic noise between stations to bring out similar signals including those related to change in river discharge
- Collect data during river flooding (Feb.) and minimal discharge (Sept.) to better **accentuate river signals**
- Identify other signals present in spectrogram to **better understand campus activities**
- Investigate correlation of ballistic signals to distant earthquakes

## REFERENCES

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