Jennette’s Pier Hydrophone Spectral Analysis:

Software Design, Implementation, and Testing

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Contents

Version History

Version#	***Date***	***Author***	***Description***
1.0	06/24/2022	S.Lockhart	• Initial release generates sample plots (PSD, decidecadal spectrum) as per IEC Technical Specification, for a specified wav file
1.1	07/02/2022	“”	• Added a quality check on time series, skipping windows that seem to have a discontinuity.
1.2	Pending	“”	• Add wind-speed/rain-rate bins. • Although the software has been extended to work with OOI data, this version of the document focuses on the CSI data from Jennette’s Pier.

Introduction

At Jennette's Pier, the Coastal Studies Institute maintains a wave energy testing facility. At this site, hydrophones were deployed periodically from ??? to ??? to record ??? The hydrophone's recordings are stored as wav files.

In this project, we analyze the hydrophone data from Jennette's Pier, providing plots of power spectral density (PSD) as well as the decidecadal power spectrum. These plots are generated per wav file. The spectral analysis adheres to the IEC Technical Specification (IEC TS 62600-40, Edition 1.0 2019-06).

We also group the recordings into bins based upon environmental factors that contribute to ambient noise, specifically wind-speed and rain-rate. We then generate plots of power spectral density (PSD) and decidecadal power spectrum per wind-speed/rain-rate bin.

The purpose of this document is to describe the software that we developed for this project. We document the design (process and data), implementation, and testing.

Process views

Step 1: Calculate Power Spectral Density (PSD) per window, per wav file

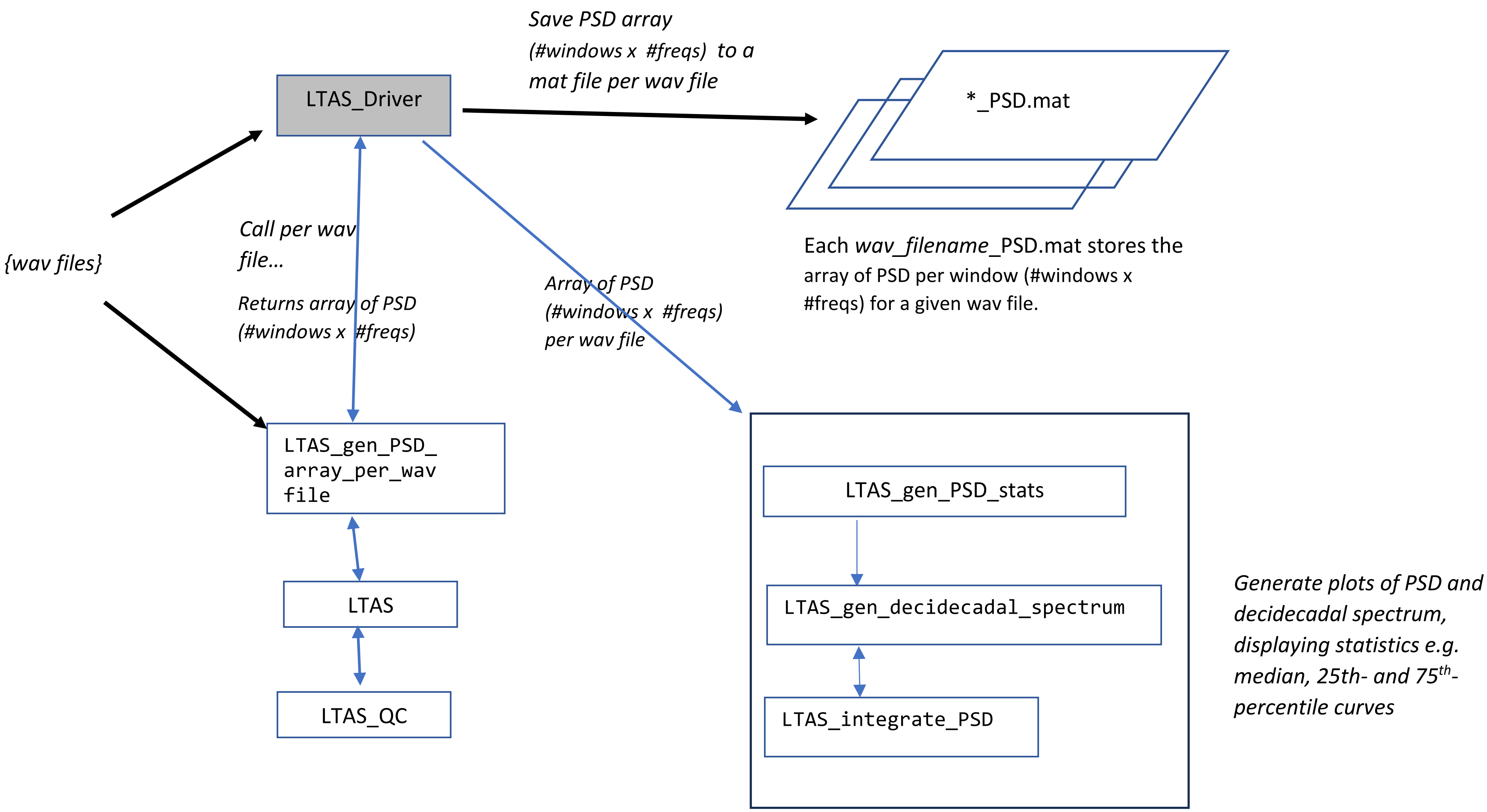

Figure 1(a): Flow diagram for “Step 1” of the spectral analysis code for Jeanette’s Pier data. Each rectangle represents a matlab function or script. A blue arrow indicates a call from one program to another. A black arrow indicates data flow. The gray shading indicates a main program. The output mat file is drawn as a parallelogram.

Step 2: Group wav files (by filename) into wind-speed/rain-rate bins

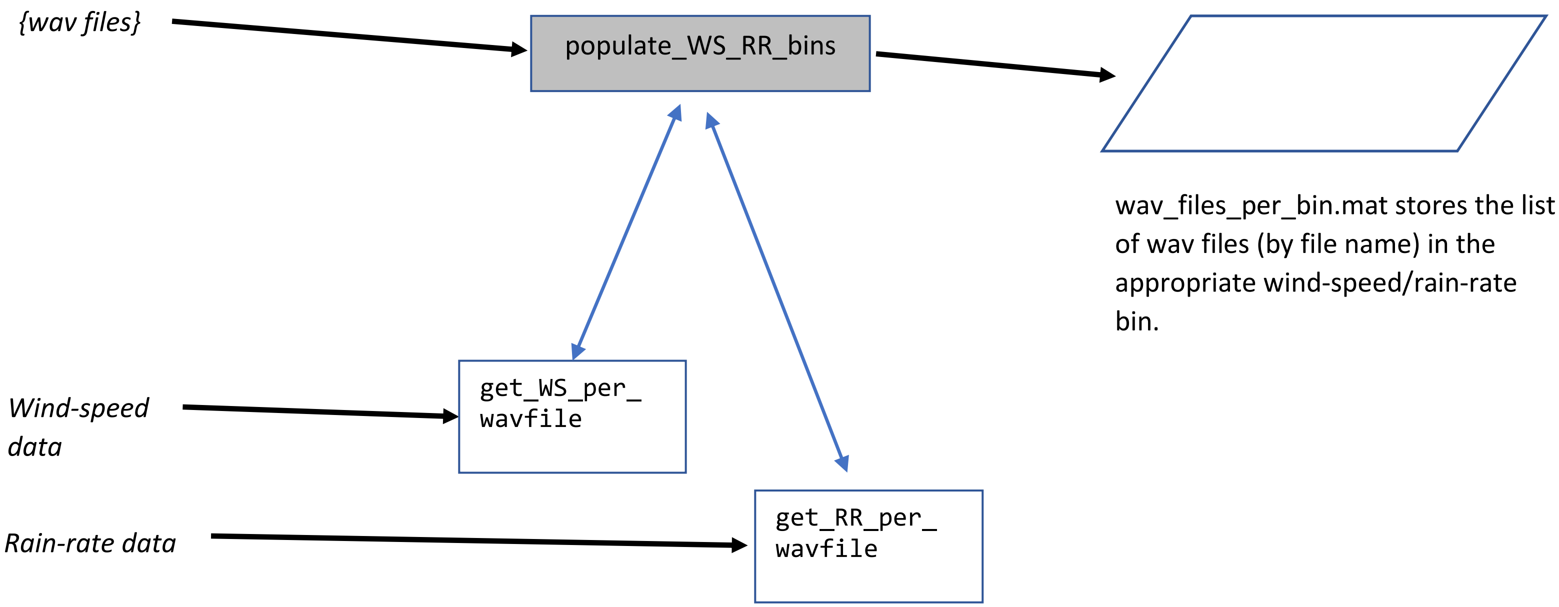

Figure 1(b): Flow diagram for “Step 2” of the spectral analysis code for Jeanette’s Pier data. Each rectangle represents a python function or script. A blue arrow indicates a call from one program to another. A black arrow indicates data flow. The gray shading indicates a main program. The output mat file is drawn as a parallelogram.

Step 3: Power Spectral Density (and spectrum) per wind-speed/rain-rate bin

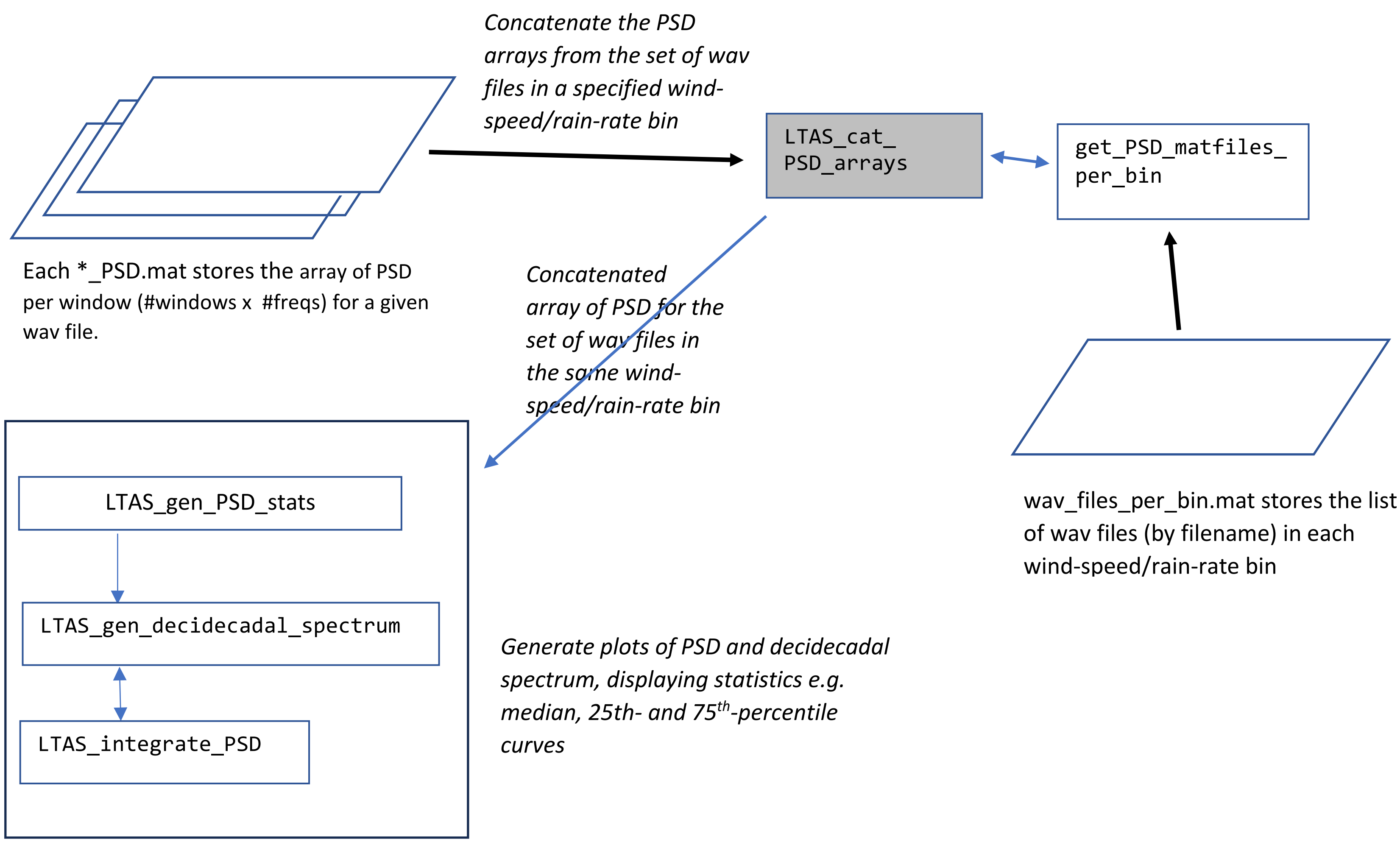

Figure 1(c): Flow diagram for "Step 3" of the spectral analysis code for Jeanette's Pier data. Each rectangle represents a matlab function or script. A blue arrow indicates a call from one program to another. A black arrow indicates data flow. The gray shading indicates a main program. The mat file is drawn as a parallelogram.

Data Views

wav files

The wav files are downloaded from dropbox into the local file system, where each hydrophone deployment has a separate folder, containing one or more wav files.

Source(s) of wind-speed/Rain-rate data

wav files assigned to bins

The wav_files_per_bin.mat stores the following data (using an example):

ws_rr_bin =

struct with fields:

wav_filename_sans_ext_array: {'SCW1984_20210421_132000' } % cell array of one or more filenames (without extension) in this bin

ws_range: [0 3] % wind-speed range in m/s for this bin

rr_range: [0 5]   % rain-rate range in mm/hr for this bin

PSD mat file

There is a PSD mat file per wav file. It stores the following:

- PSD_per_window_cal is an array of dimension #windows x #freqs, storing the magnitude of the PSD in $\mu Pa^2/Hz$
- frequency_Hz is the associated frequency values, of dimension #freqs x 1

The file naming convention for the PSD mat file is to use the wav file name (minus the .wav extension) and add _PSD.mat. Therefore, when we group wav files into bins by wav filename, we know which PSD mat files to concatenate together.

All *_PSD.mat files are stored in the same directory in the file system. This makes it easier to concatenate them together.

The concatenated PSD array is not saved; it exists only in memory.

Assumptions/prerequisites regarding the data

The table below documents assumptions made regarding the data.

Short Description	***Long Description***
wav sample rate	To generate spectral plots per wind-speed/rain-rate bin, the appropriate PSD arrays (of dimension #windows x #freqs) are concatenated. Therefore, the wav files must all have the same sample rate. If this is not the case, the software generates a warning and skips the wav file.
wav file names	We assume wav file names are unique. This is relevant because we use the wav file name as part of the PSD mat file name, and we store all of the PSD mat files in the same folder.

Data quality checks

Discontinuity

The LTAS program calculates the power spectral density for each 1-second window. The windows are 50% overlapping.

However, if a 1-second window contains a discontinuity which is above a threshold, the window is skipped. Figure ??? shows an example of a discontinuity.

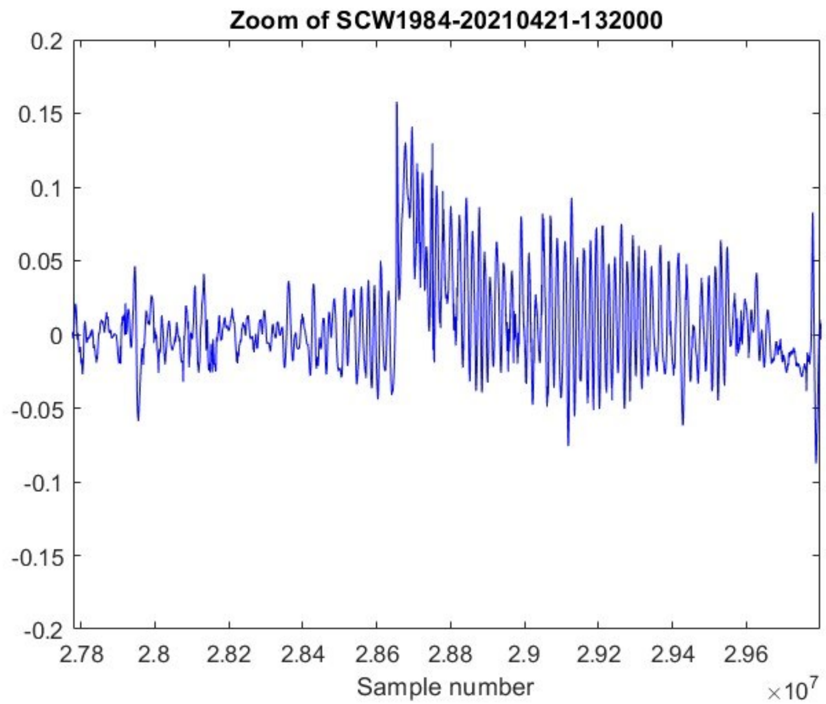

Figure ???: An example of a discontinuity in the recording.

A discontinuity in the time series may exist in the following scenario:

- The hydrophone is recording at a high sample rate; however, it fails to store a buffer of data before the next buffer is ready to be stored. In this case, it may skip a buffer (or part of a buffer).
- The device does not record a timestamp for each sample; instead, we just *assume* the time series is continuous—that consecutive samples are separated by the sample interval.

Implementation views

Programming language

The current implementation uses Matlab. A python implementation will be developed soon.

Code availability

The Matlab implementation is available in github at:

https://github.com/sblockhartzzero/CSI_JP_SpectralAnalysis_Matlab

How to run

Before running the code, perform the following prerequisite steps:

- Download the Jennette's Pier hydrophone wav files from dropbox onto your local filesystem
- Obtain the source data files for wind-speed and rain-rate. (See "Data views" section above.)
- Customize the code, editing the main programs, (LTAS_Driver.m, ???, LTAS_cat_PSD_arrays.m) to point to the folders on your file system.

For each step, run the appropriate main program:

- For step 1, run LTAS_Driver.m. This program processes all the wav files in a folder. If you have a folder per hydrophone deployment (as we did), then you'll need to run this program once per hydrophone deployment.
- For step 2, run ??? As in step 1, this program processes all the wav files in a folder. If you have a folder per hydrophone deployment (as we did), then you'll need to run this program once per hydrophone deployment.
- Note that steps 1 and 2 are independent i.e. you can switch the order; however, they must both be completed before running step 3.
- For step 3, run LTAS_cat_PSD_arrays.m. This program processes a single, specified (wind-speed bin, rain-rate bin).

Sample Plots

Step 1: Calculate Power Spectral Density (PSD) per window, per wav file

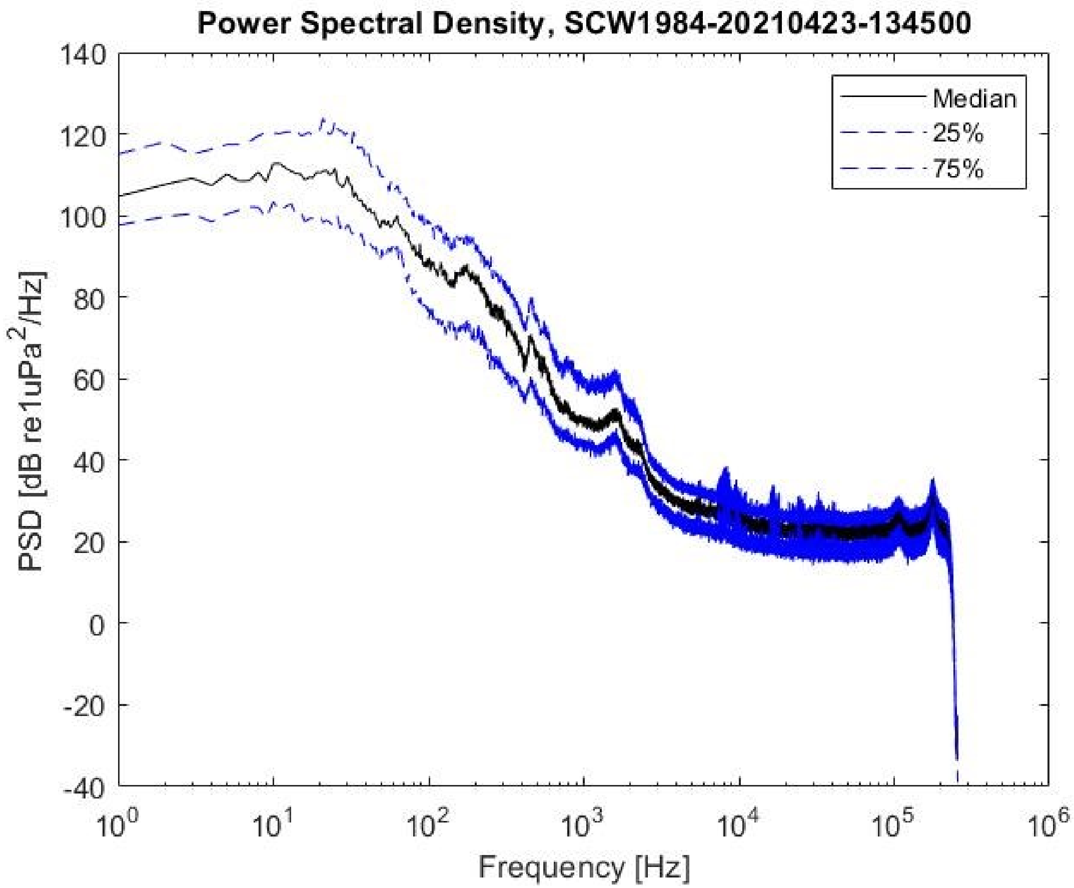

Figure ???: Sample plot of power spectral density for a specified wav file.

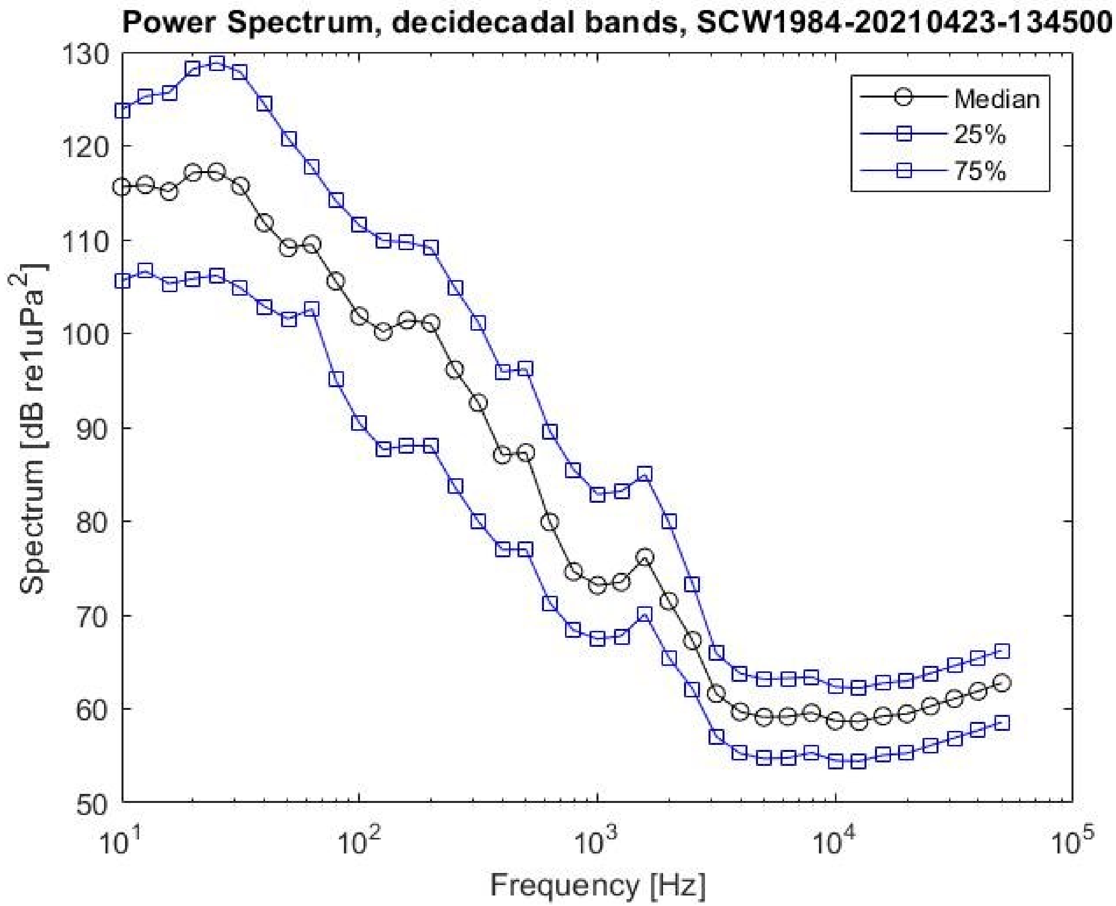

Figure ???: Sample plot of power spectrum over decidecadal bands for a specified wav file.

Step 2: Group wav files (by filename) into wind-speed/rain-rate bins

Step 3: Power Spectral Density (and spectrum) per wind-speed/rain-rate bin

Calibration

Testing