ME 297 Advanced Computational Data Analysis- Final Report

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Background

Hot-wire anemometry is a measurement technique used to determine the velocity of fluids in the gas phase. Hot-wire anemometry is commonly used in aerodynamics research and engineering applications such as wind tunnel testing, combustion analysis, and HVAC system design. It involves the use of a small wire, typically made of tungsten or platinum, which is heated to a high temperature using an electrical current; see Figure 1 for different probes. As the fluid flows passes the wire, the temperature of the wire drops, causing a change in its resistance. This change in resistance can be measured and calibrated to calculate the velocity of the fluid.

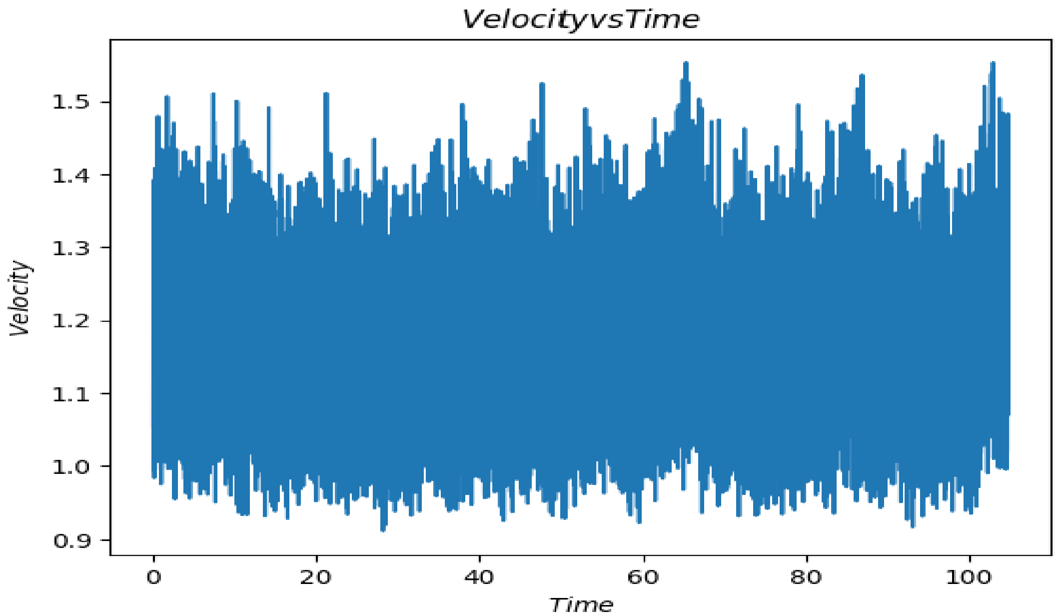
Problems

For the given data (first column = time, and the second column = voltage change), accessible via Canvas course shell under the corresponding assignment, do the following:

1. (10 points) Read the signal using your scripting language of choice, that is MATLAB, Python, or Julia,
and use the following calibration curve to convert the change in voltage to velocity.
(Voltage +1)2 = 0.3224 × u0.46 + 0.5143
where u is the instantaneous velocity. Once the velocity is obtained, plot the record versus time.

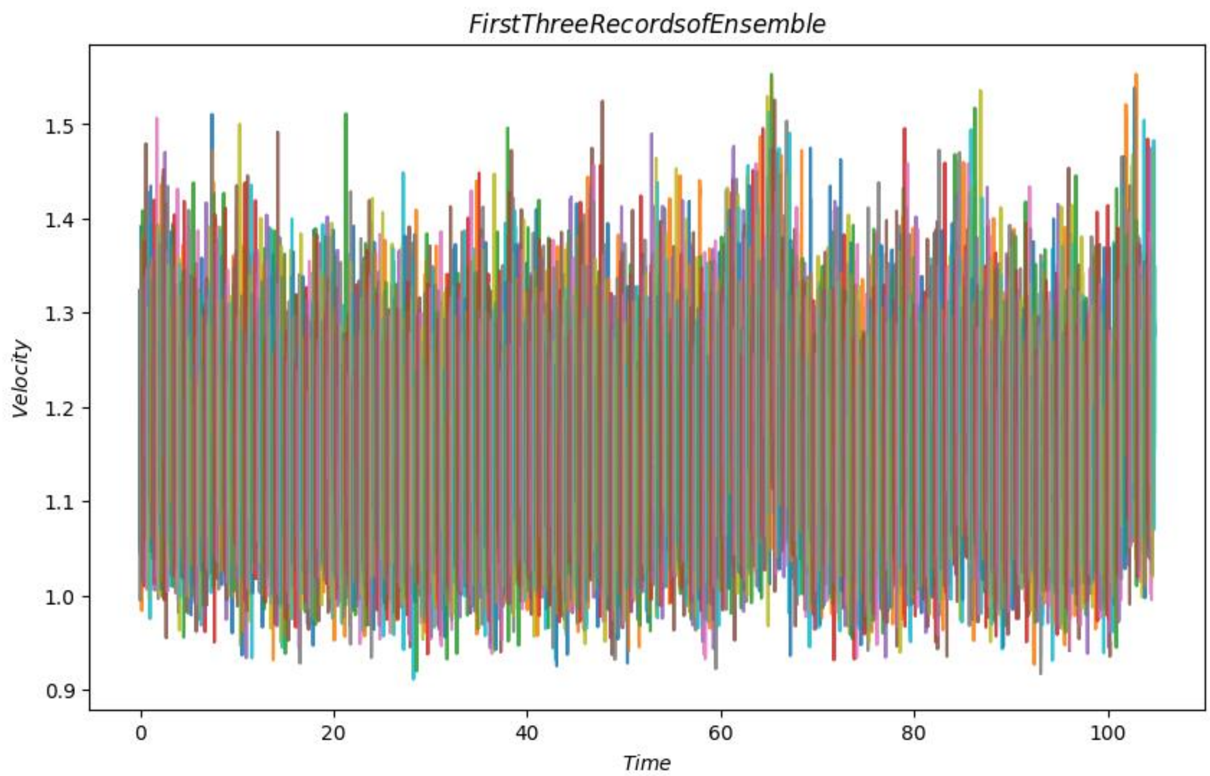
```
#1  Reading the signal using the python
# Define the voltage to velocity conversion function
def voltage_to_velocity(Voltage):
    u = (((Voltage+1)**2 - 0.5143)/0.3224)**(0.46)
    return u;
```

Plotting the results in the below image using python



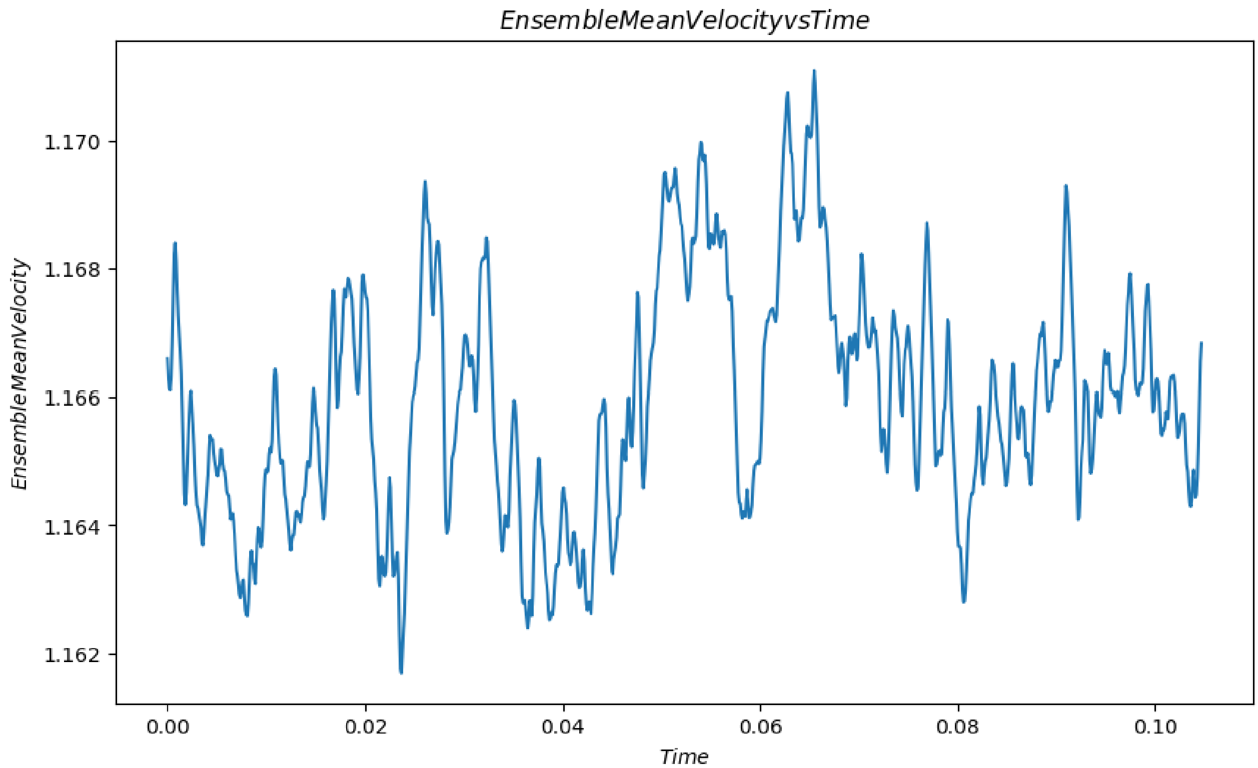
2. (15 points) The signal is very long; in these situations, it is common to divide the signal in equal chunks
and create an ensemble. Create an ensemble of 1000 signals and plot the first three records versus
time.

In the below image we can see the plot between the first three records vs time.



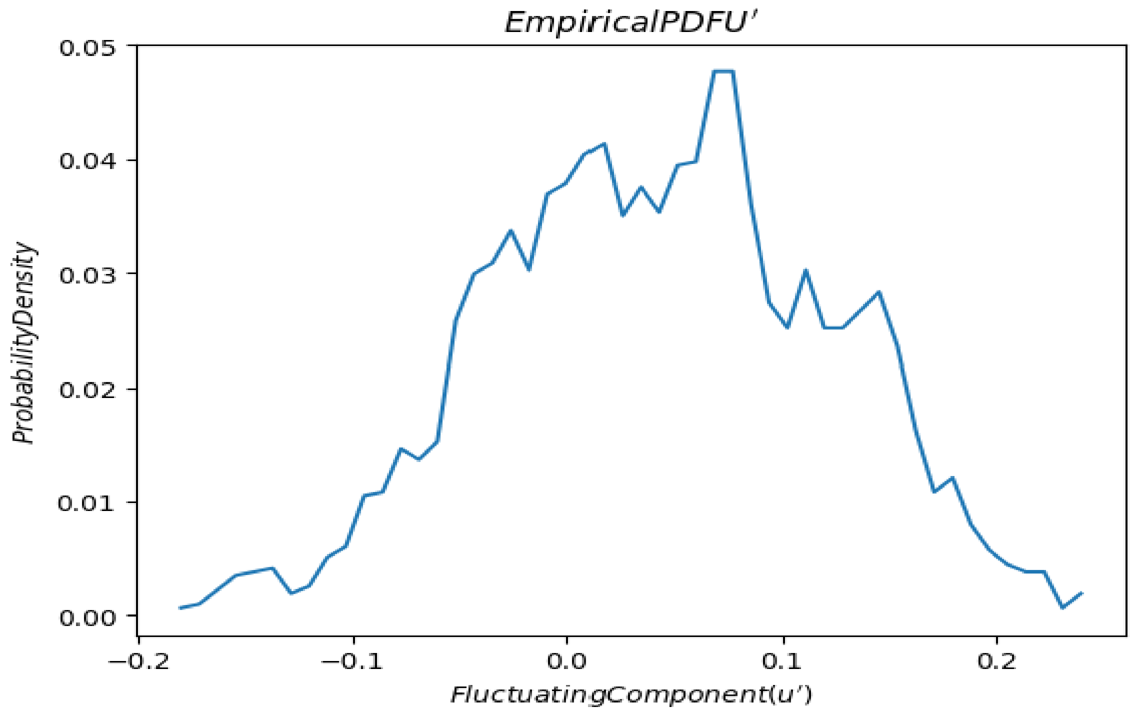
3. (10 points) Calculate the ensemble mean velocity and visualize it against time.

In the below image the data is visualized using the plot between ensemble mean vs time.



4. Reynolds decomposition separates a turbulent velocity signal (u) into the mean (time-averaged) component (U) and the fluctuating component (u′). As a result, one can show the instantaneous velocity as $u(t) = U(t) + u'(t)$.

1. (15 points) For the first three records in the ensemble, calculate the empirical PDF of the u′ and visualize them.



2. (5 points) Are the obtained PDFs following the Gaussian distribution?

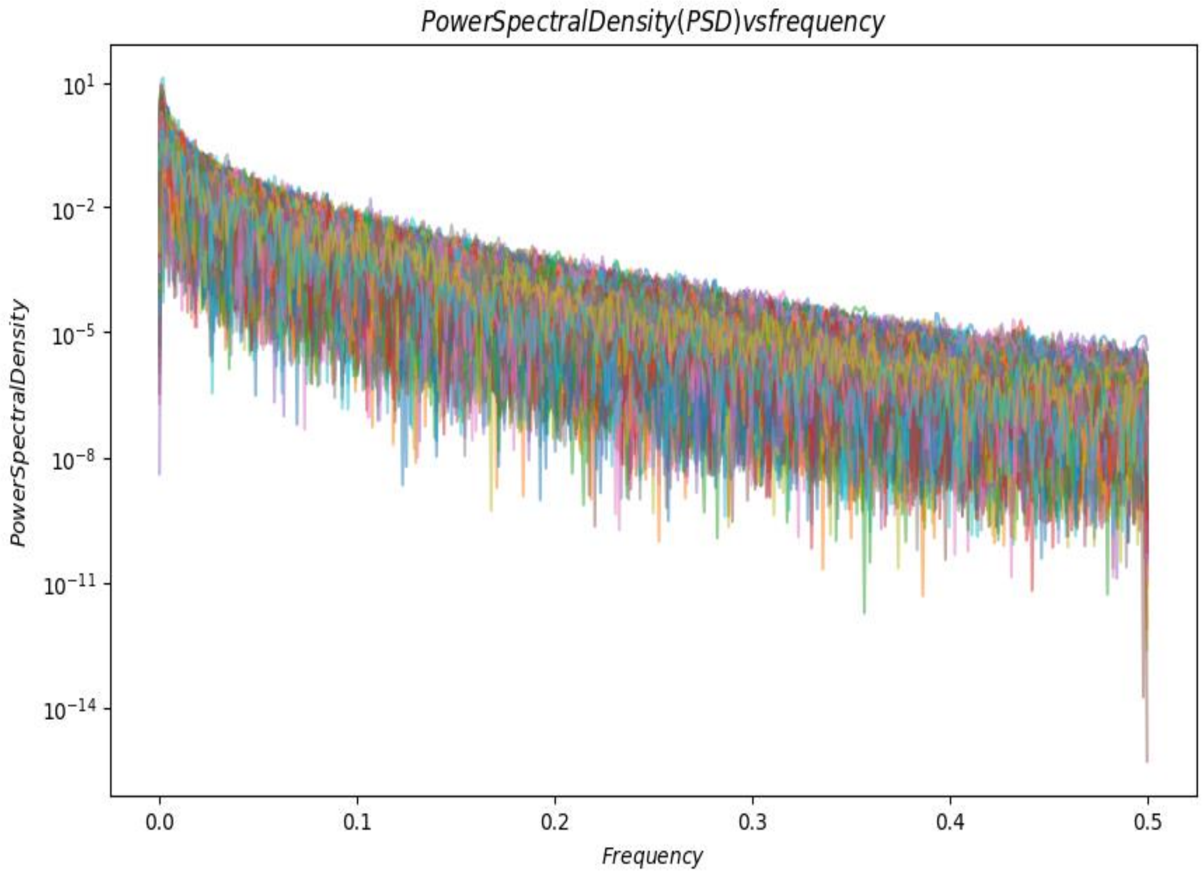
To determine whether the obtained PDFs of the fluctuating component (u') are following a Gaussian distribution, you can visually inspect the shape of the PDFs. A Gaussian distribution, also known as a normal distribution, is characterized by a symmetric bell-shaped curve.

If the PDFs exhibit a symmetric bell-shaped curve, it suggests that they may follow a Gaussian distribution. However, if the PDFs deviate significantly from a bell-shaped curve or show asymmetry, it indicates a departure from the Gaussian distribution.

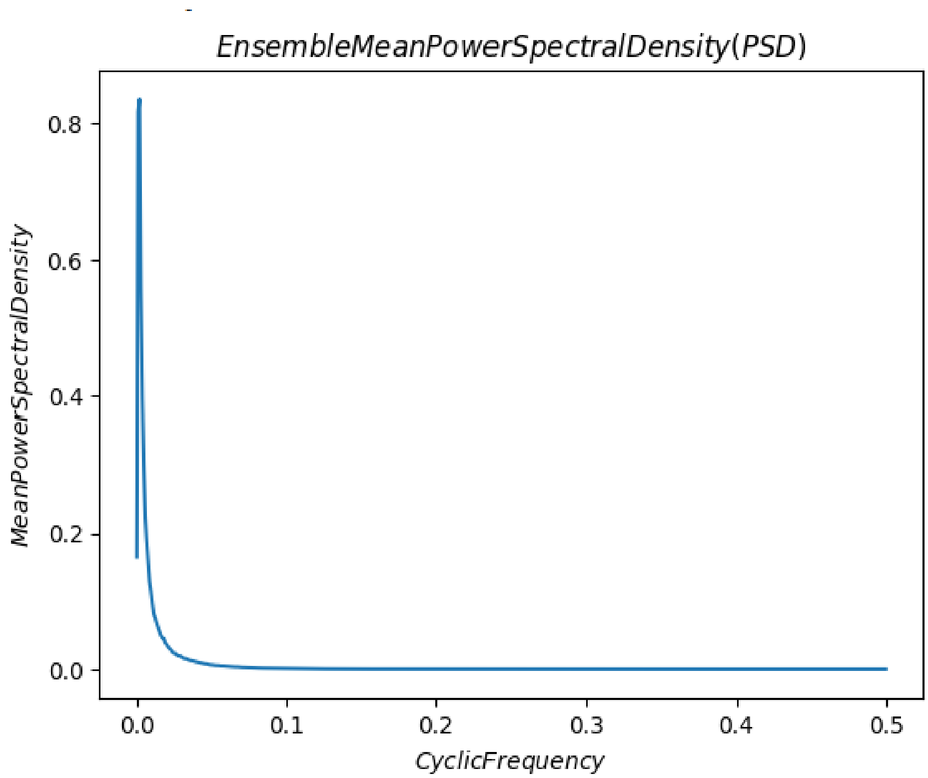
You can assess the shape of the PDFs obtained in the previous step by visually inspecting the plots. If the PDFs resemble a symmetric bell-shaped curve, it suggests that the fluctuating component follows a Gaussian distribution to some extent. On the other hand, if the PDFs display significant deviations from a bell-shaped curve, it indicates a departure from the Gaussian distribution.

Inspecting the plots of the empirical PDFs of the fluctuating component (u') will provide insights into their shape and whether they approximate a Gaussian distribution.

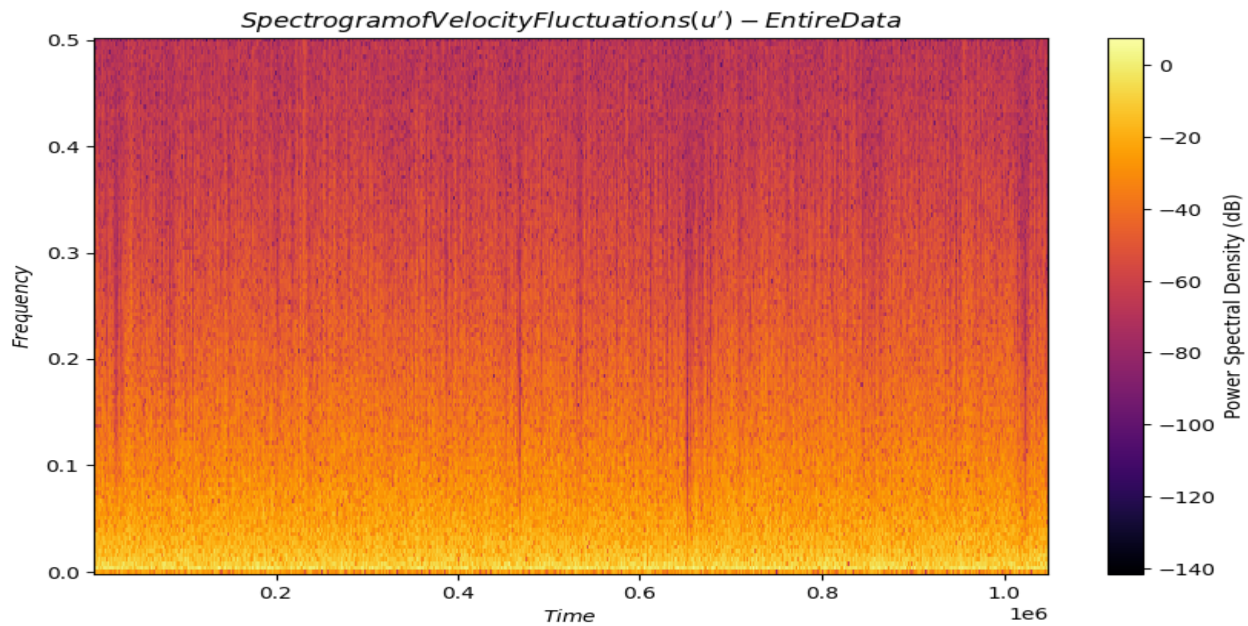
3. (10 points) For each record (realization) in the ensemble, calculate the power spectral density (PSD) for the u′.



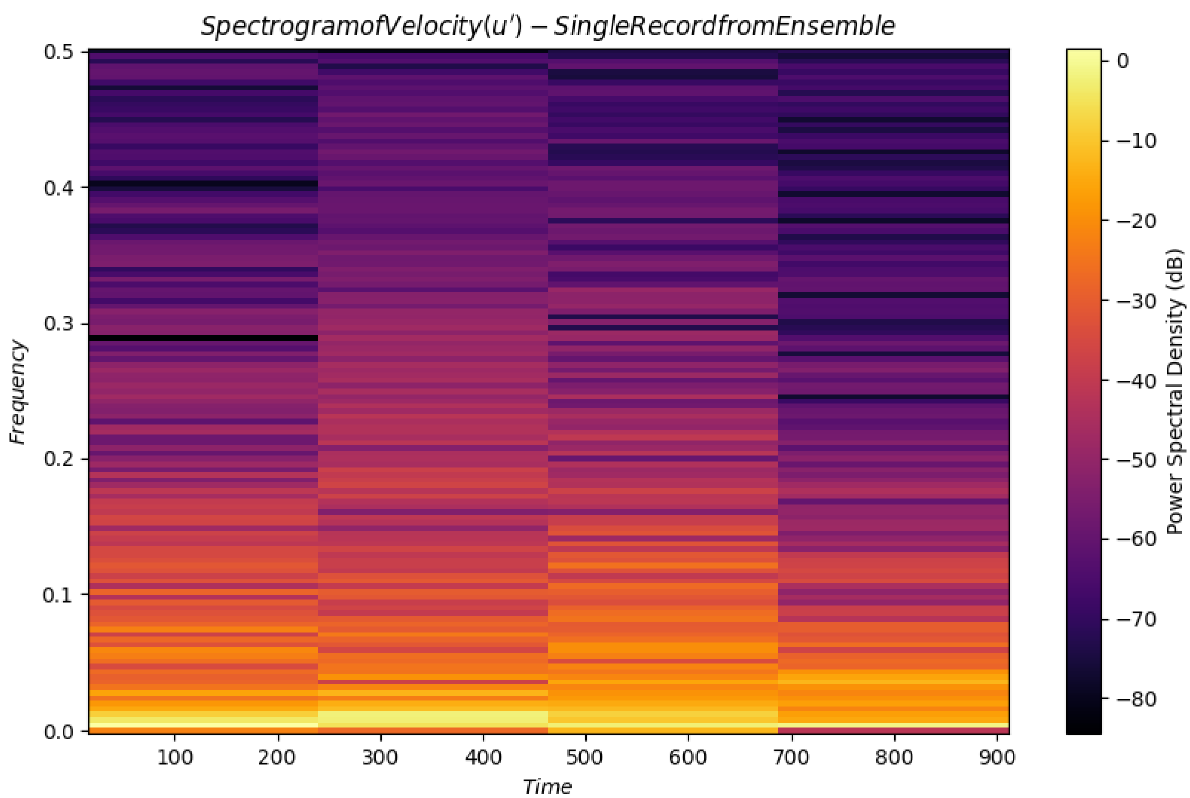
4. (10 points) Calculate the ensemble mean of the PSDs in part 4.3. and visualize it against the cyclic frequency.



5. (25 points) Calculate and visualize the spectrogram of the velocity fluctuations u' for the entire data (not the created ensemble in problem 2). Compare this with a spectrogram of a single record from the ensemble, and discuss your observations from the localization of the time and frequencies.



4.5.1 visualizing the spectrogram of the velocity fluctuations u′ for the entire data (not the created ensemble in problem



4.5.2 Visualizing the spectrogram of a single record from the ensemble.

Observations from the localization of time and frequencies:

- The spectrogram of the entire data provides an overview of the power spectral density (PSD) distribution over time and frequency for the entire dataset.
- The spectrogram of a single record from the ensemble represents the PSD distribution for that specific record.
- By comparing the two spectrograms, you can observe the differences in the PSD patterns and how they vary over time and frequency.
- The localization of time in the spectrogram indicates when certain frequencies are prominent or have higher power.
- The localization of frequencies in the spectrogram indicates which frequencies have higher power at specific time intervals.
- You can analyze the variations and similarities in the PSD patterns between the entire dataset and individual records to gain insights into the fluctuation characteristics of the velocity data.

NOTE:

The calculations are done in the code part and printed in the code that is submitted. The plots are generated after the calculations using the python programming language.