AOE 5154: Data Analysis

Proper Orthogonal Decomposition for Dimensionality Reduction and Near-Field Noise Analysis

Using the Welch Method for Power Spectral Density Estimation

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November 2023

Data

1

Source:
- Mach 1.5 time-resolved supersonic jet planar velocity data.
- From the TRDGV Hot Jet Campaign led by Ashley J. Saltzman.

Data File:
- Instantaneous Axial Velocity (3D array).
- XD : 6mm to 17mm - YD : -1.5 mm to 1.2 mm

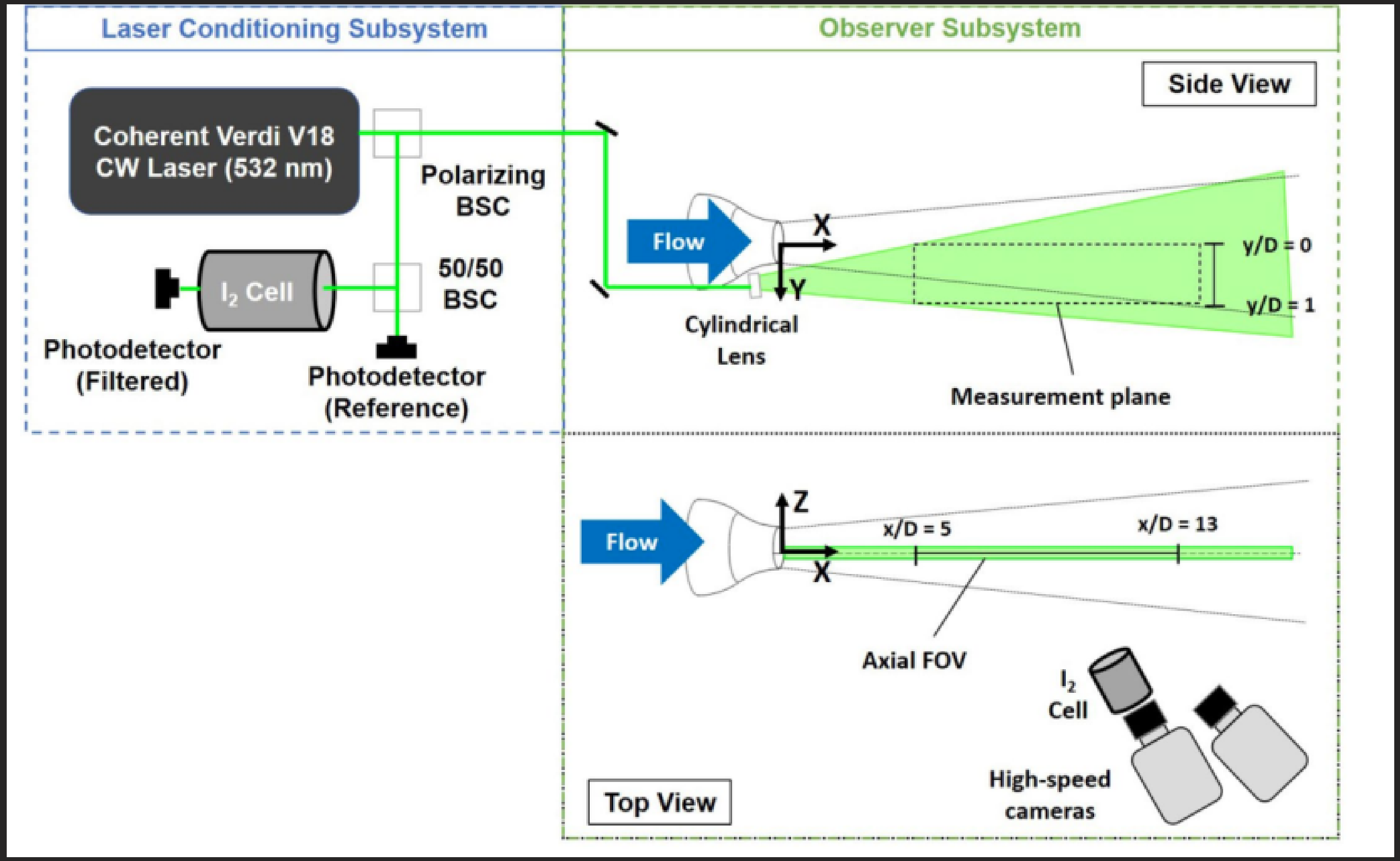
Measurement System:
- Time-Resolved Doppler Global Velocimetry.
- 100,000 consecutive data entries.
- Intervals: 20 μs.

Sample Rate: 50 kHz.

Objective:
- Study significant-scale turbulent

Wave number (k) = 1.8790*10^4

Time bins for PSD = 250



Setup[1]

The Impact of Data Analysis

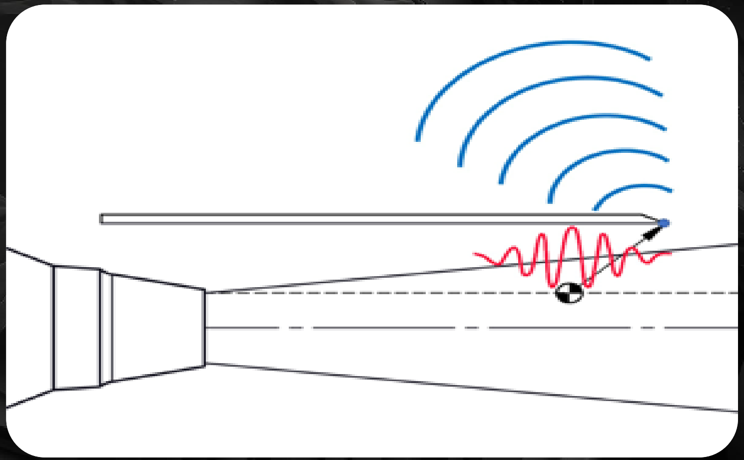
1 SVD-based Proper Orthogonal Decomposition

2

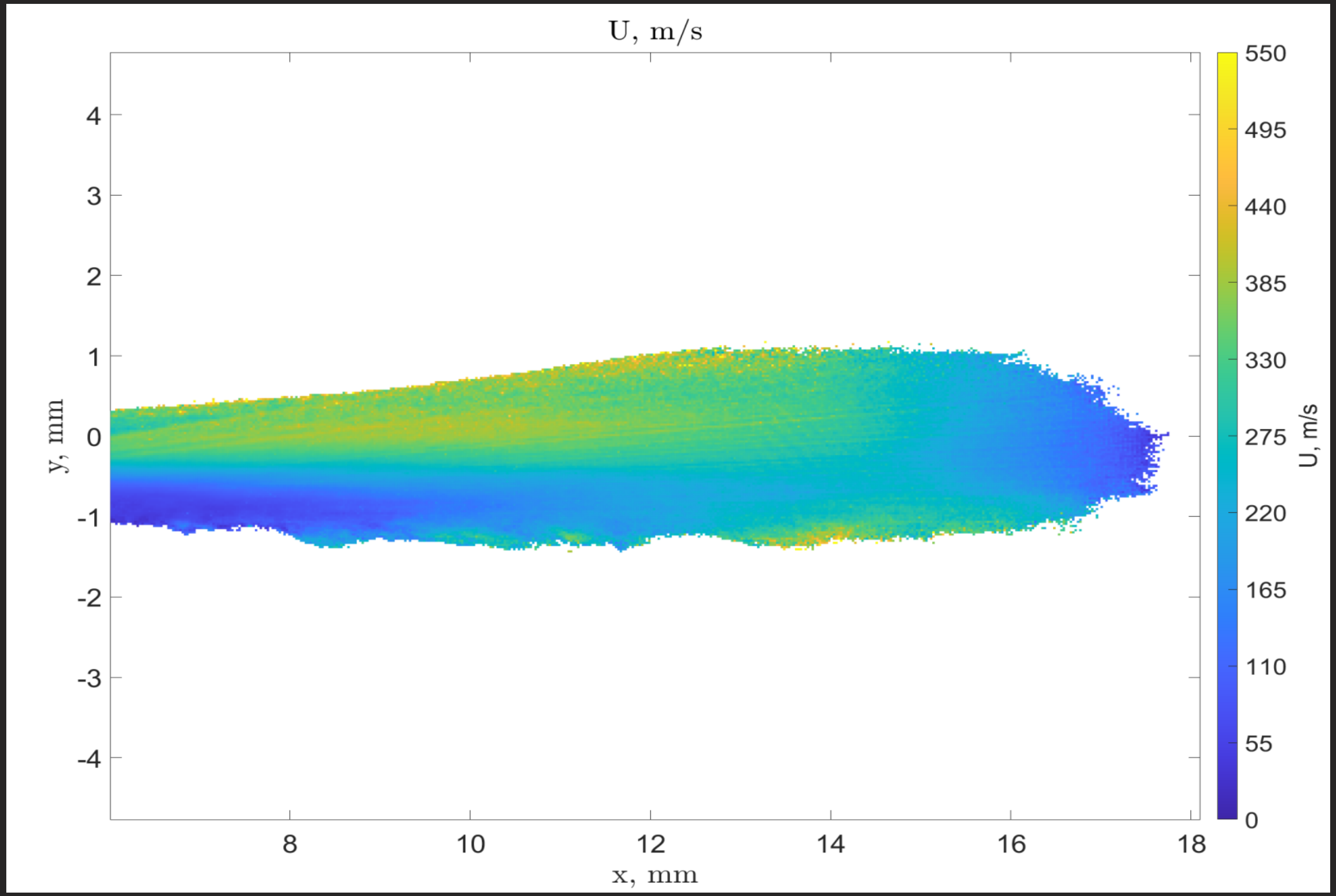
- Power Spectral Density by Welch:
  Analyzing the frequency content using Welch's method.
- PSD as a Function of Helmholtz Number (κr_0)[4]:where κ is the wave number and r_0 is the distance from the center of the eddy to the edge of the half plane.

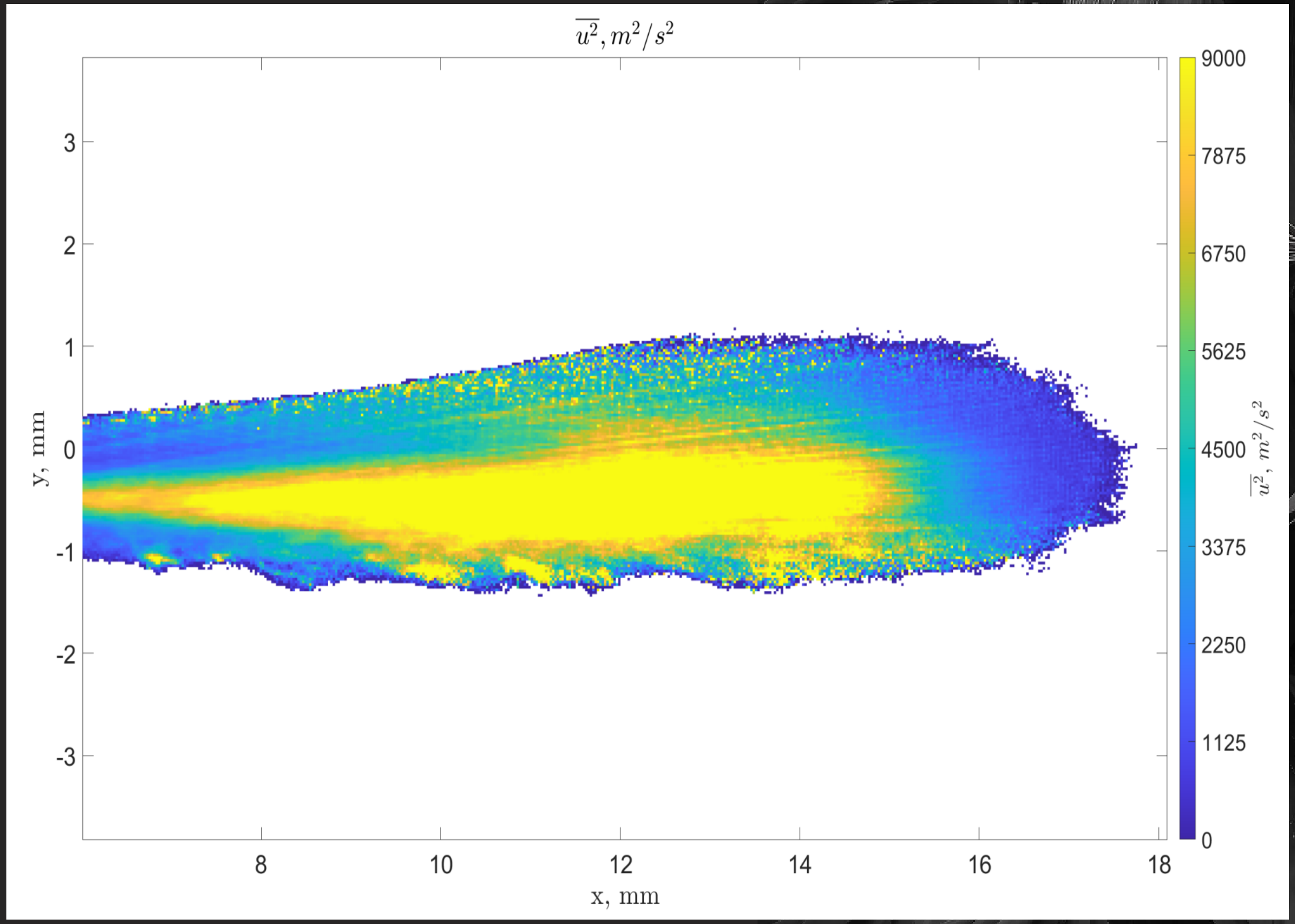
3

- Near Field Noise Analysis:
Analyzing noise characteristics near a specific point (XD: 13.0790 mm, YD: 0.3166 mm) with high auto-correlation along the edge, while ignoring noise.



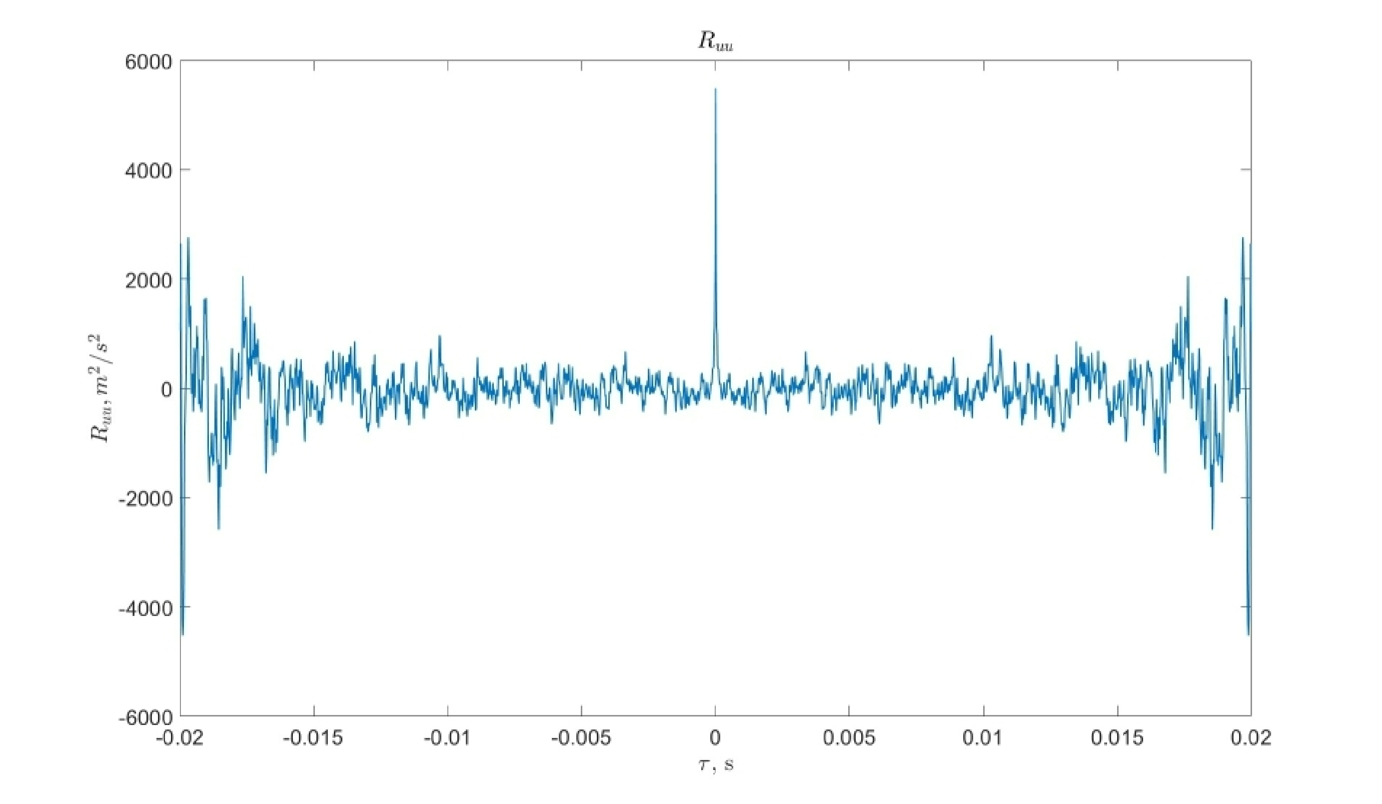
Mean and Variance





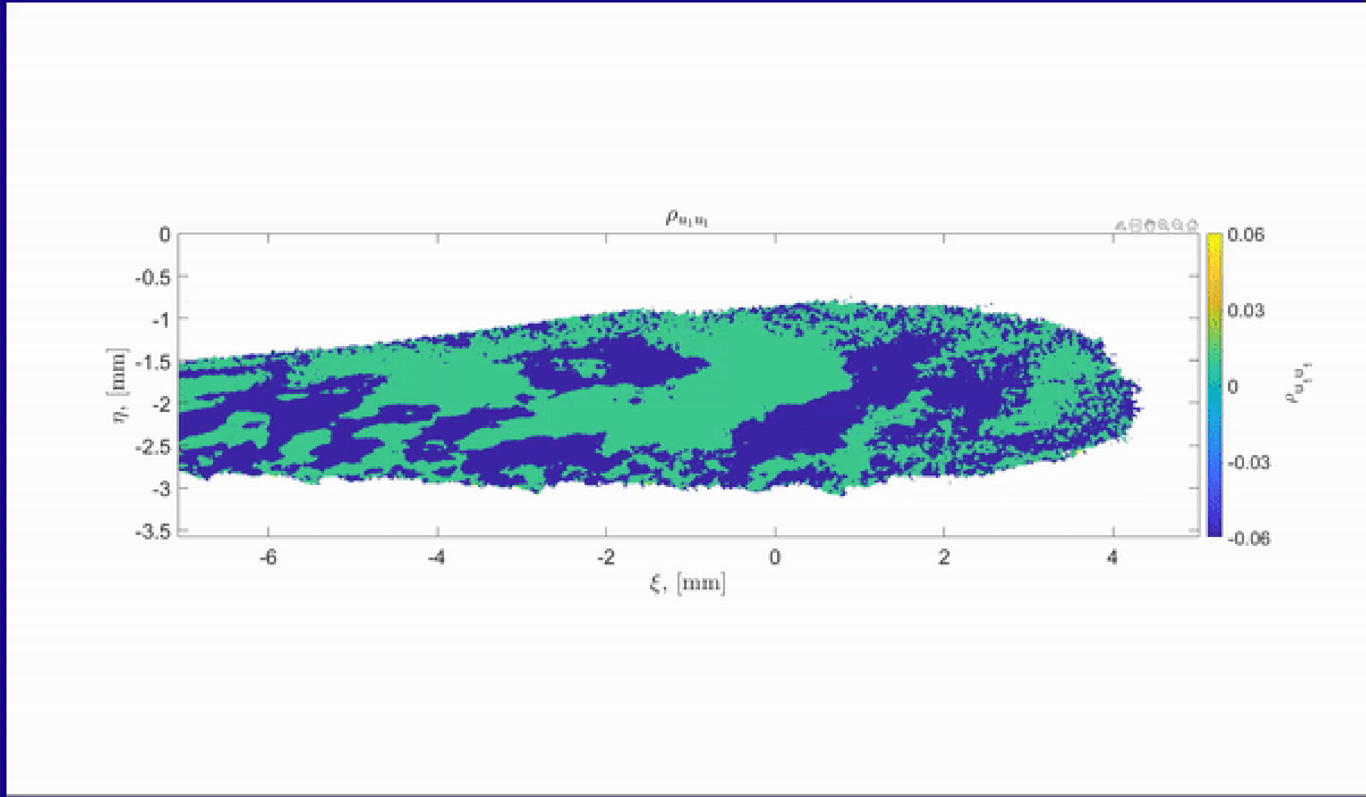
POD results

Average auto correlation at point of interest up to 2 s



XD: 13.0790 mm, YD: 0.3166 mm

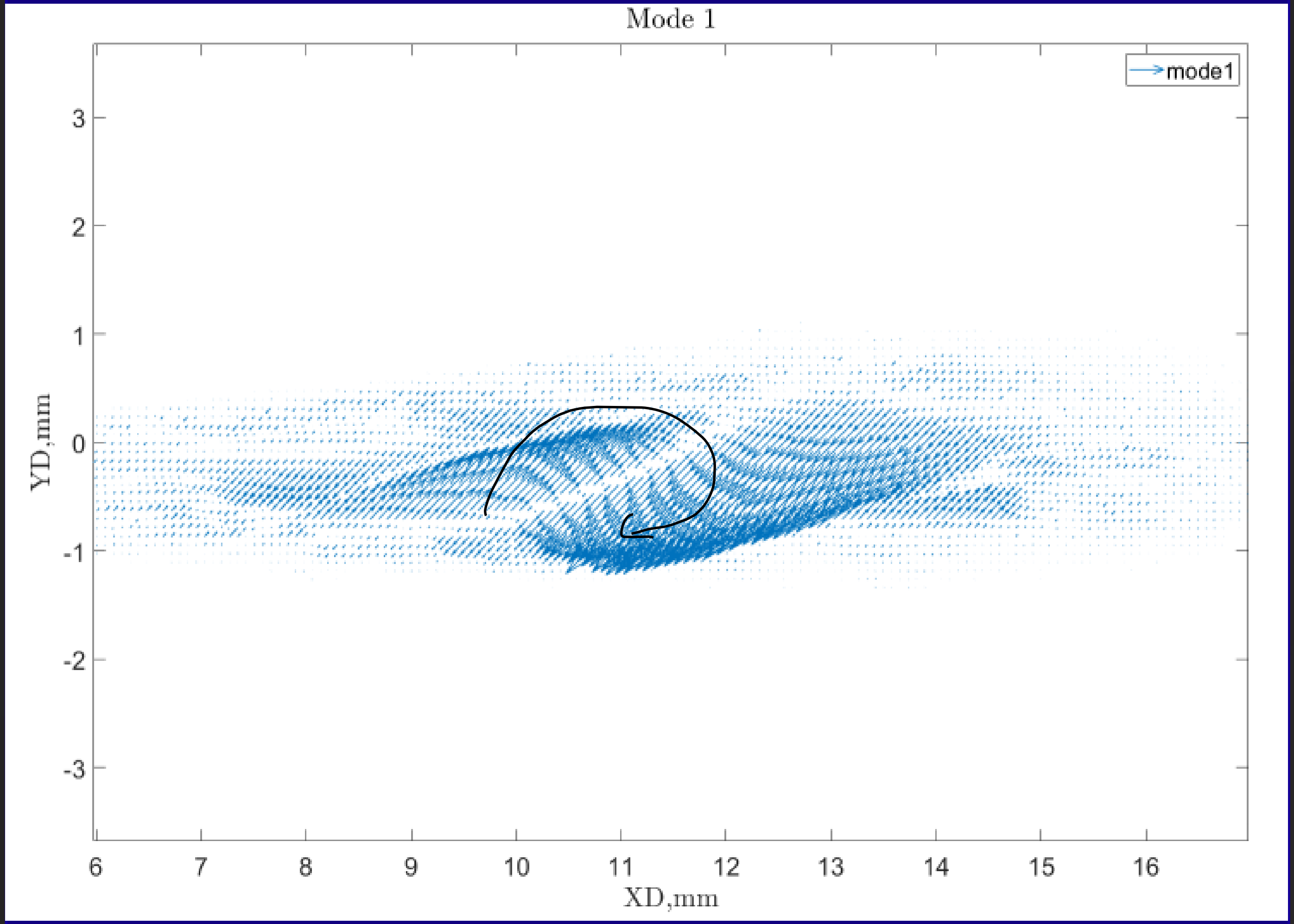
Two-point correlation for every 0.04 s up to 1 s



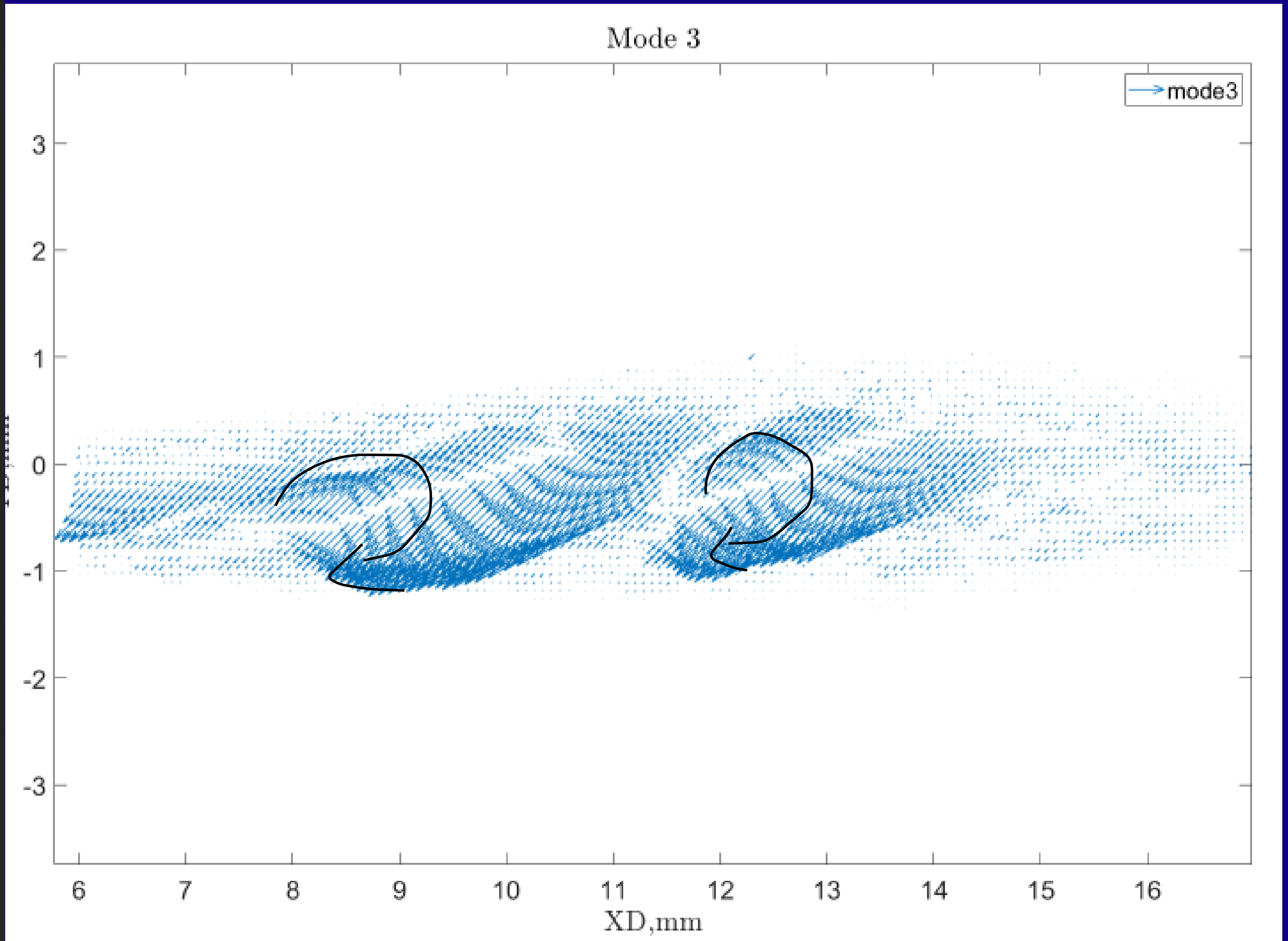
Taylor Microscale (λ) = 0.0557 mm

POD results

Mode 1

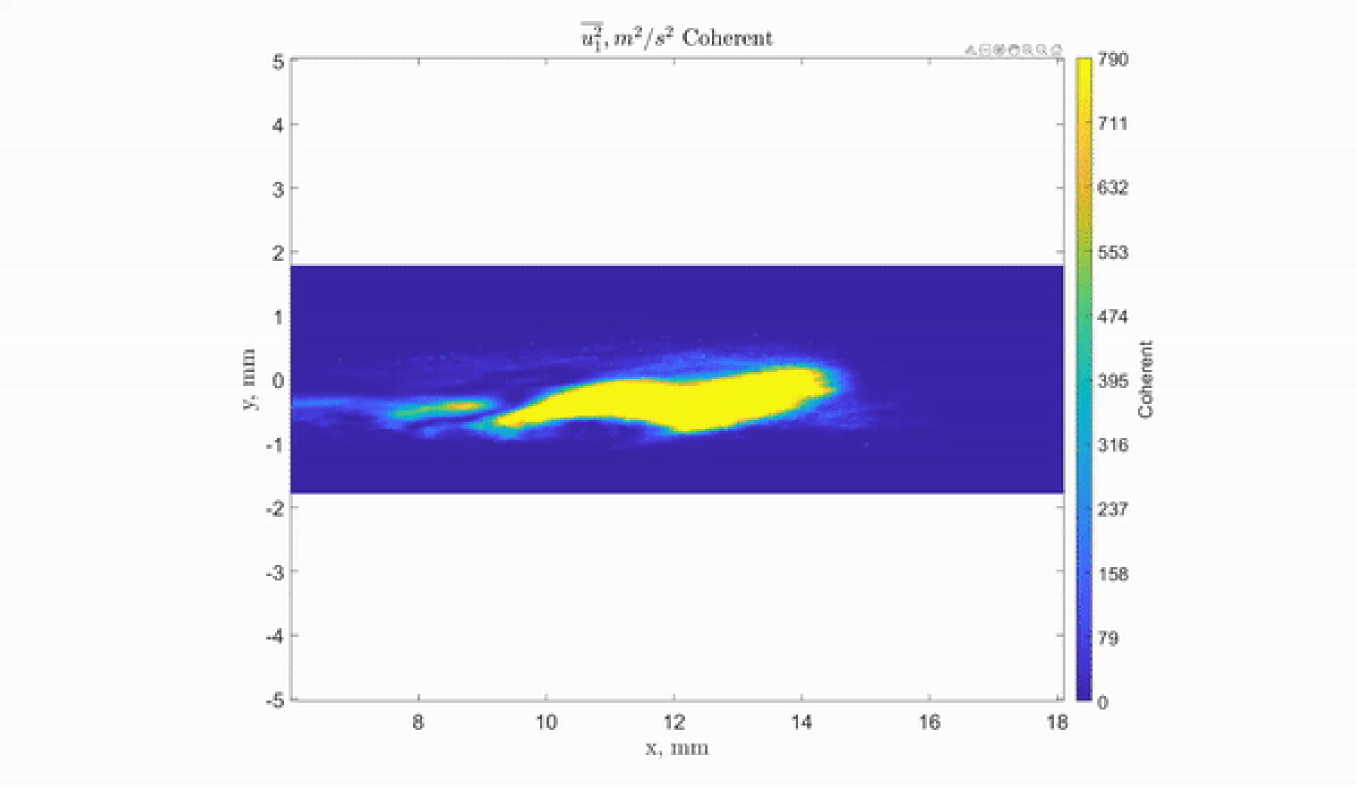


Mode 3



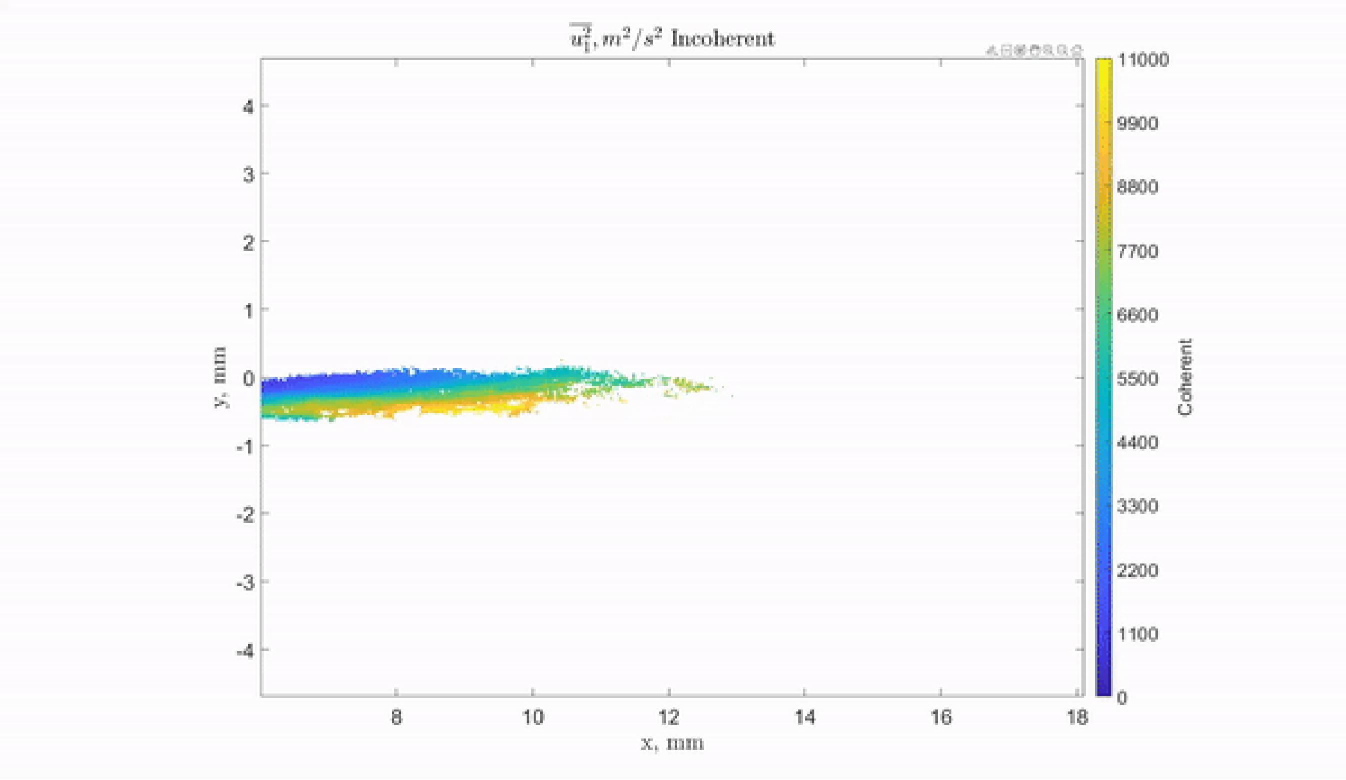
POD results

Coherent



Large Eddy's forming at the center

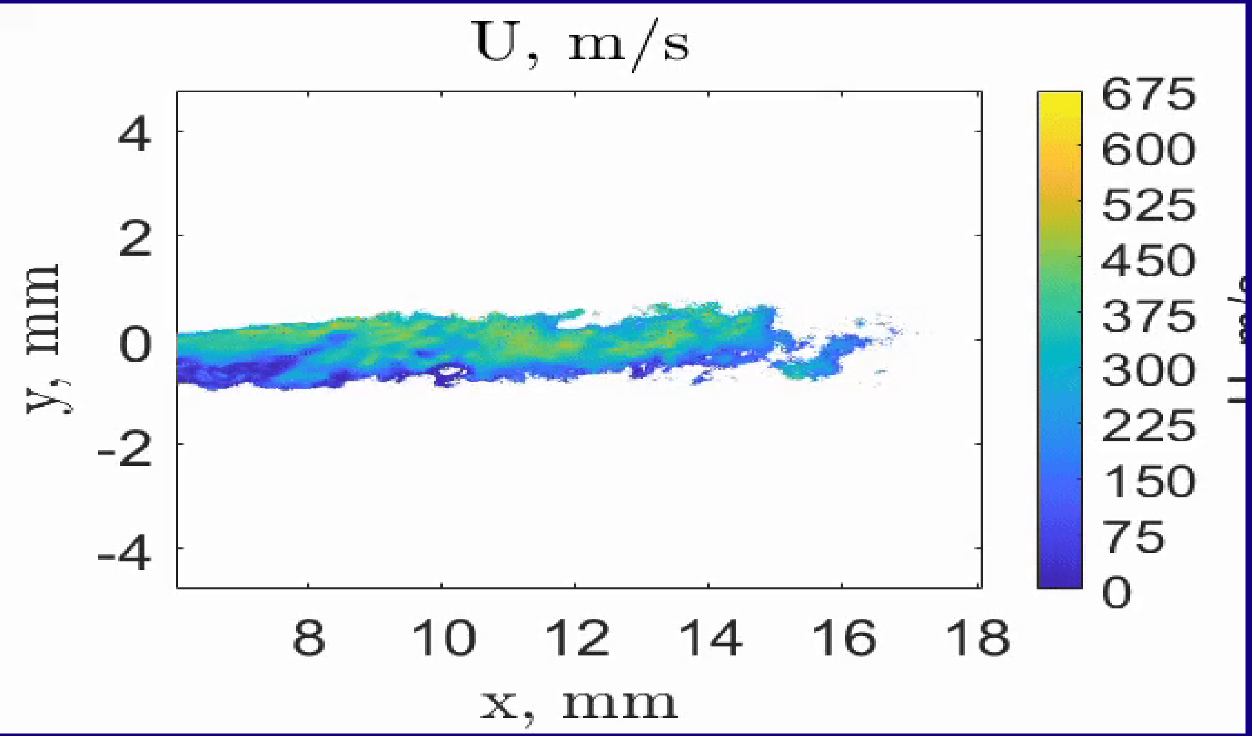
Incoherent



The jet outlet having the incoherent modes being more relevant

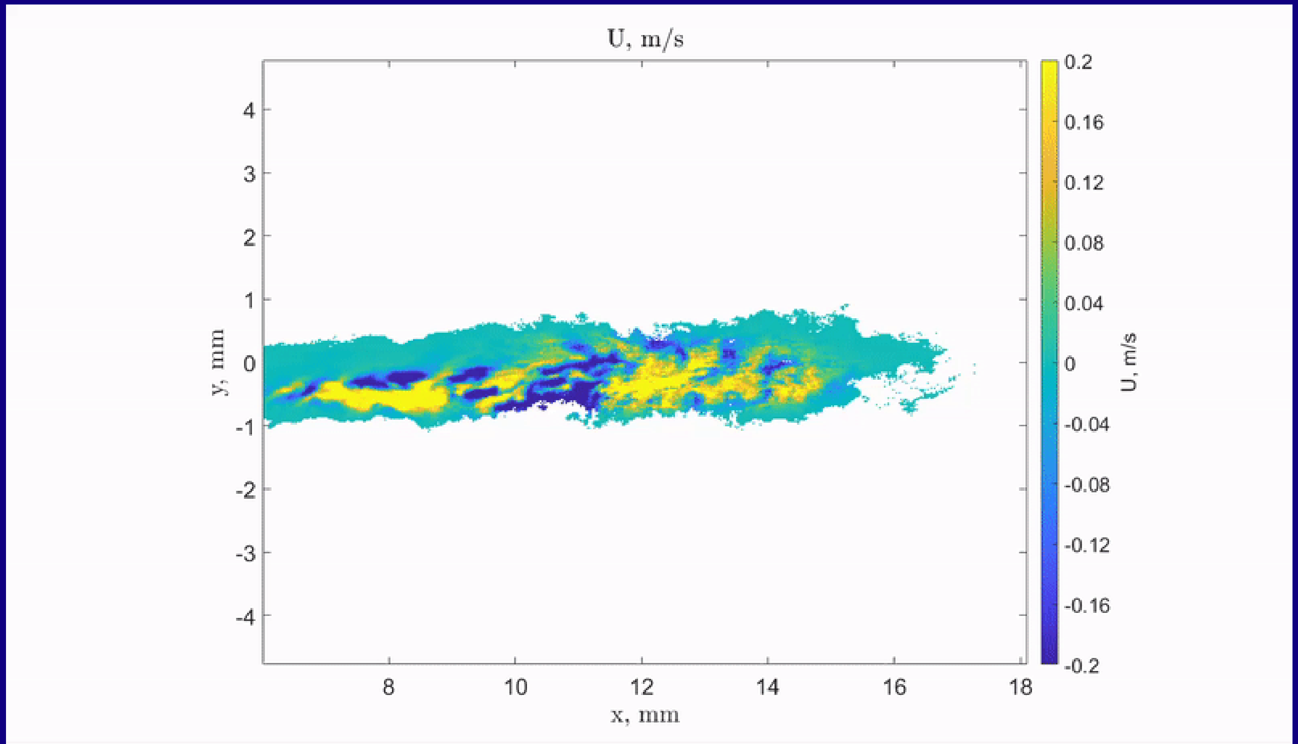
POD results

Original



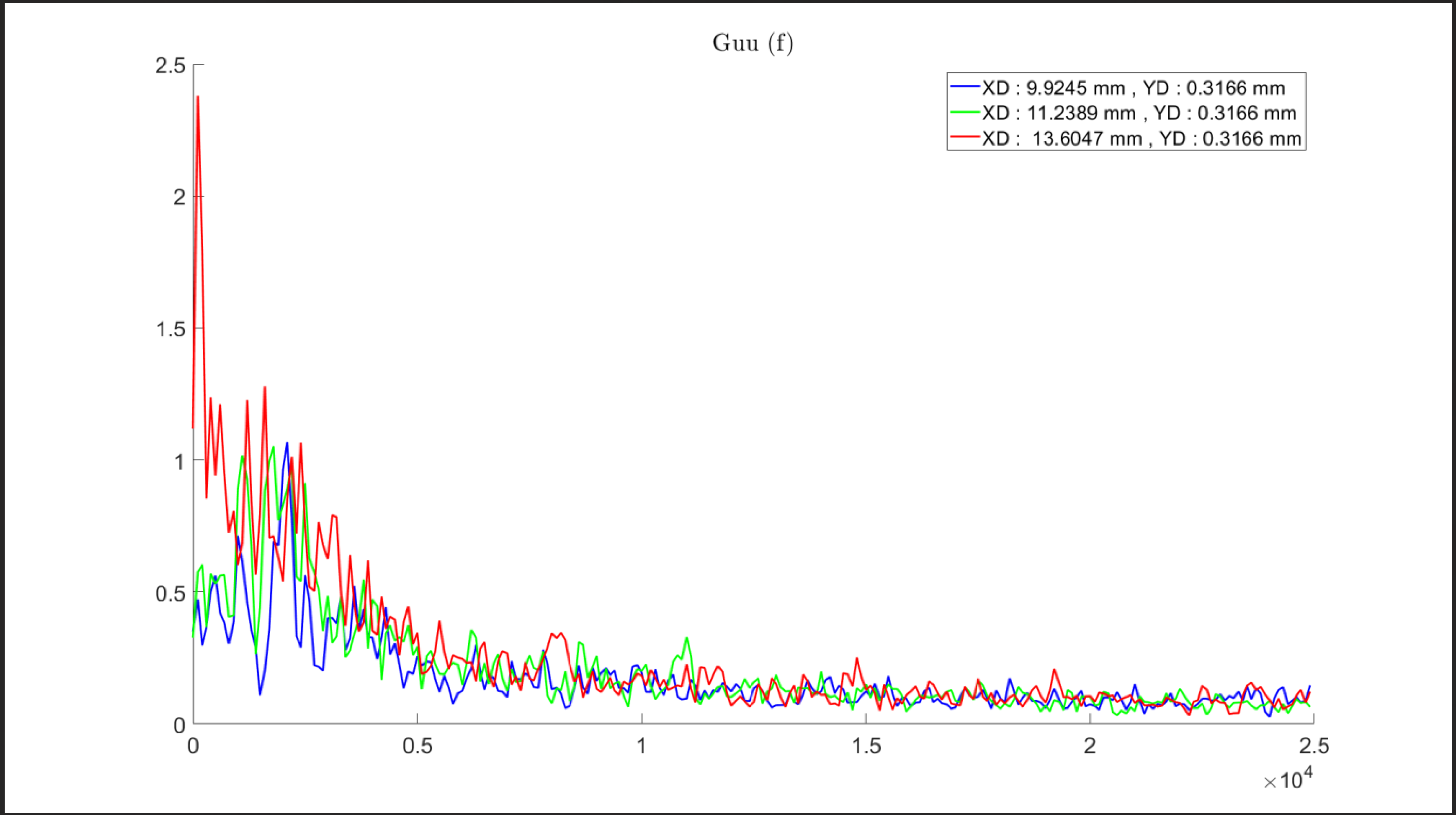
Raw data of the instantaneous velocity

Reconstructed



Reconstructed data (from the first 20 modes)

PSD results



Power spectral density plot along the upper edge, downstream of the flow. Showing higher power as it moves downward. This is due the source of the noise being situated close to the trailing edge, enough to produce hydrodynamic pressure variation that gets dissipated as noise.

Conclusion

1. **Data Analysis**

   Loaded the data as effectively as possible in the given time and reduced using SVD-POD. Analyzed for its different behaviors.

2. **Important data retained**

   Data was reconstructed for 20 modes.

3. **Study of noise using PSD**

   Choose anchor points along the border with high auto correlation to focus on near field noise.

Merci

References

[1] Saltzman, Ashley J., et al. “50 Khz Doppler Global Velocimetry for the Study of Large-Scale Turbulence in Supersonic Flows.” Experiments in Fluids, vol. 62, no. 9, 2021, https://doi.org/10.1007/s00348-021-03286-5.

[2] Schmidt, O. T., & Colonius, T. (2020). Guide to Spectral Proper Orthogonal Decomposition. AIAA Journal, 58(3), 1023–1033. https://doi.org/10.2514/1.J058809

[3] Proper Orthogonal Decomposition—An overview | ScienceDirect Topics. (n.d.). Retrieved September 1, 2023, from https://www.sciencedirect.com/topics/computer-science/proper-orthogonal-decomposition

[4] Rego, L., Avallone, F., Ragni, D., & Casalino, D. (2020). Jet-installation noise and near-field characteristics of jet–surface interaction. Journal of Fluid Mechanics, 895, A2. doi:10.1017/jfm.2020.294