On the Instantaneous Dynamics of the Large-Scale Structures In The Impinging Round Jet

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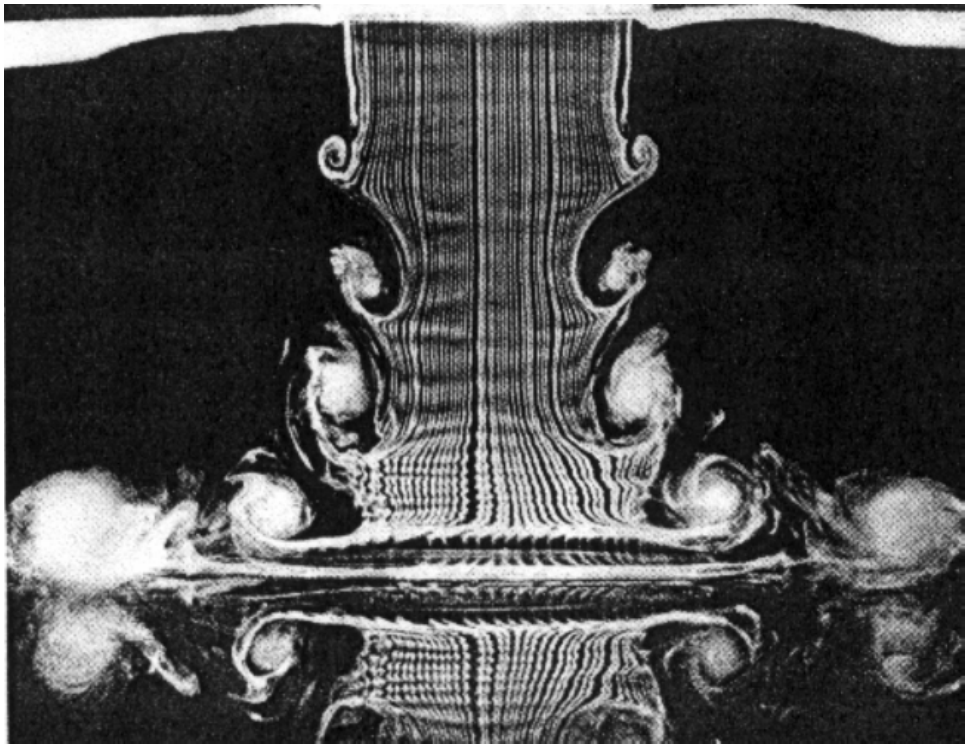
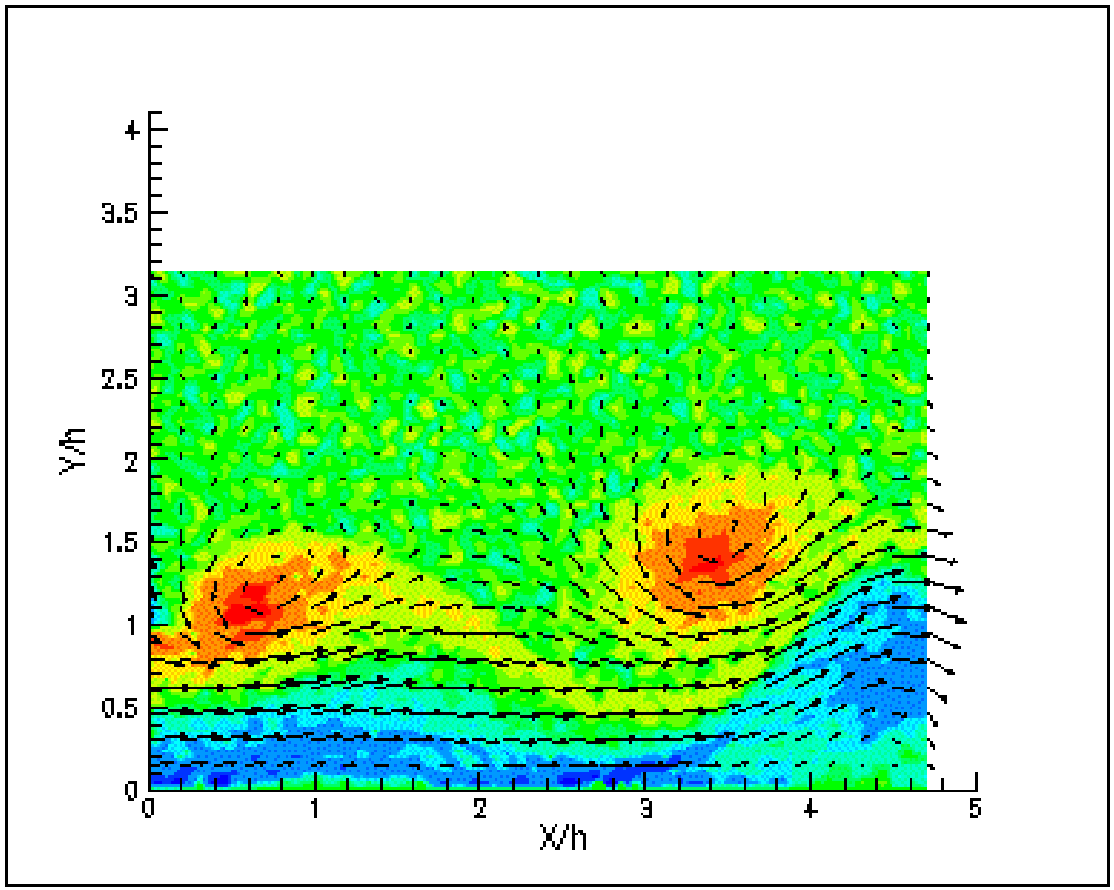
Turbulent Round Impinging Jet



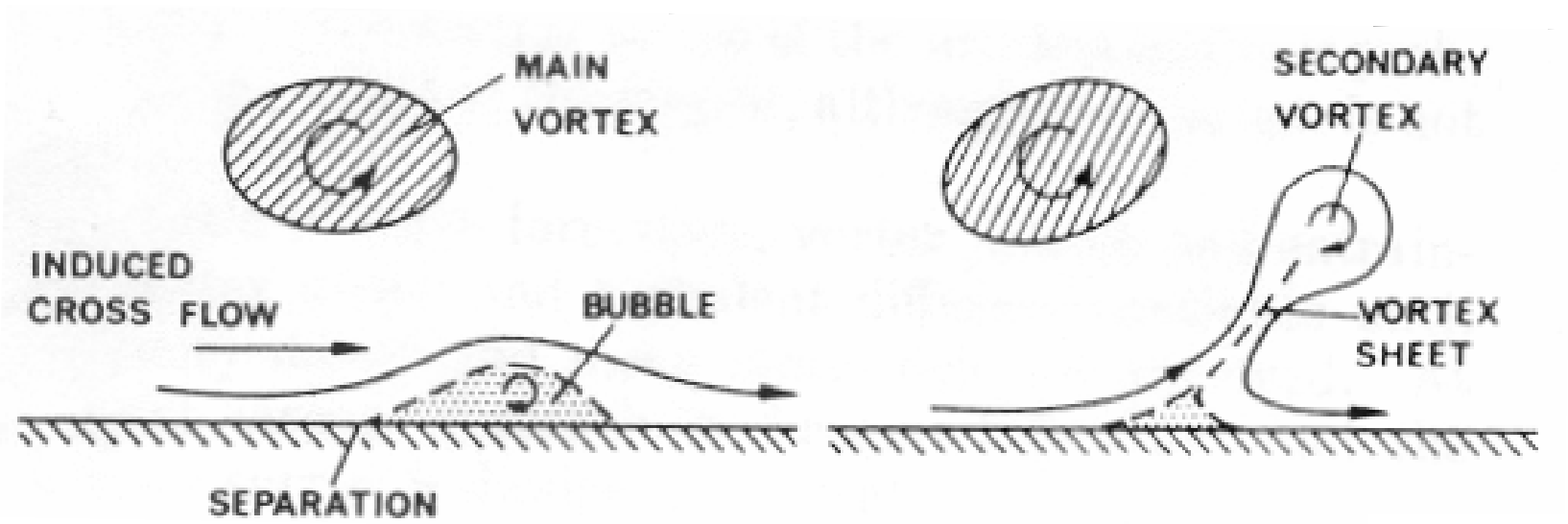
Flow visualization of impinging round jet,
H/D=2.0, Re=20000,
Popiel and Trass (1991).

Turbulent Plane Wall Jet



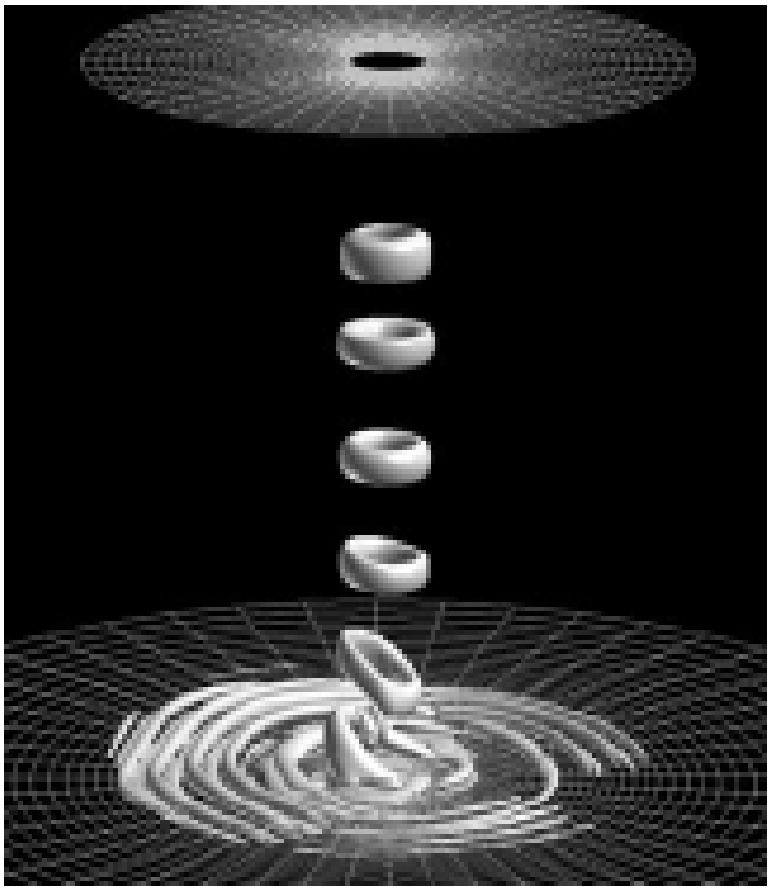
Gogineni and Shih (1997)
http://www.eng.fsu.edu/~shih/succeed/flow-vis.htm

Harvey and Perry's Rebounding Vortex



Harvey and Perry (1971)

Three-Dimensionality of Structures?

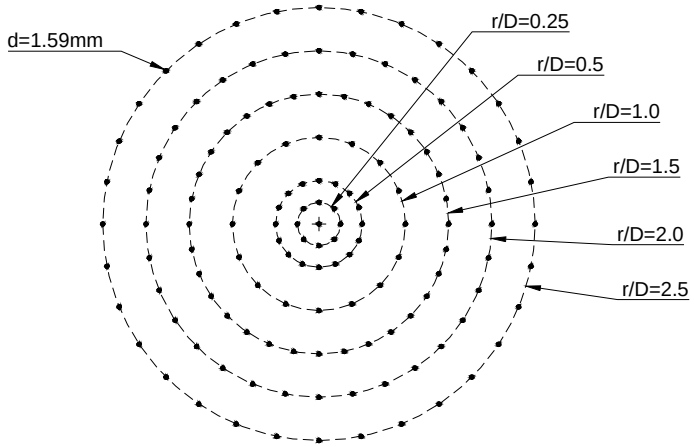


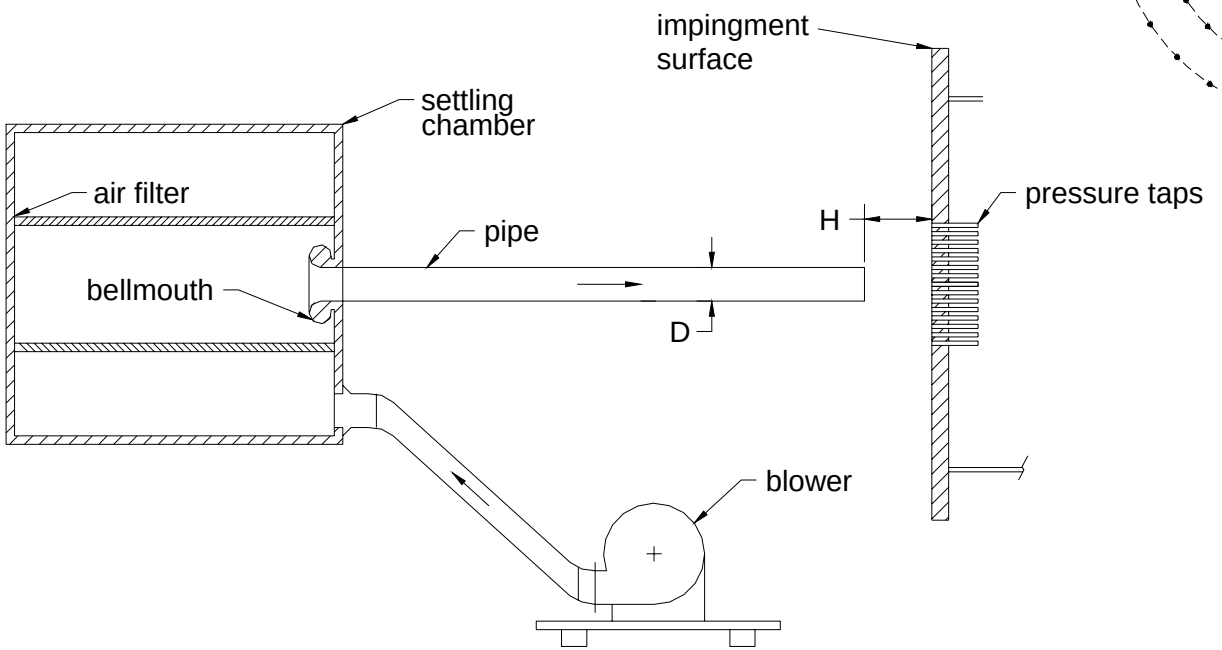
Tsubokura (2003) Re=2,000
Forced at Strouhal Frequency
Fully Developed Pipe Flow
H/D = 9

Landreth and Adrian (1991) observed instantaneous flow was not symmetric in PIV measurements

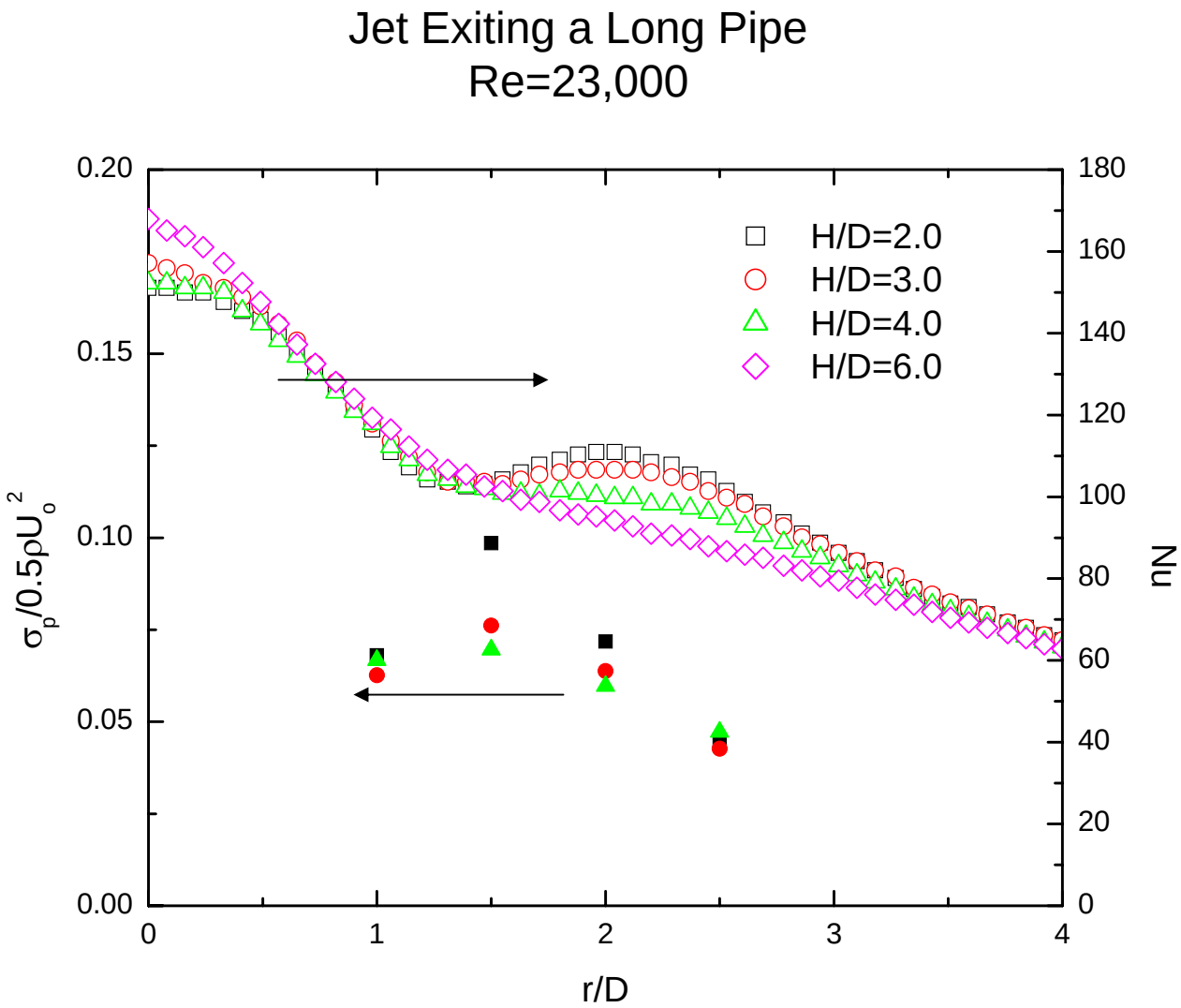
Investigation of the Three-Dimensionality of Large-Scale Structures

Hall et al (2002)





Effect of Nozzle-to-Plate Distance



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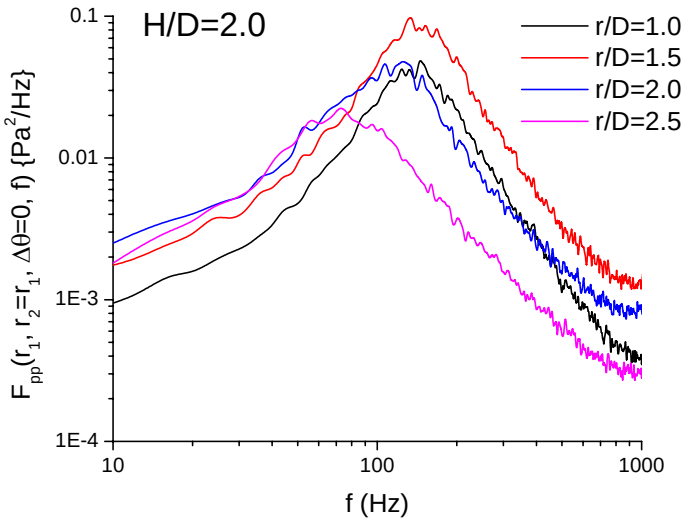
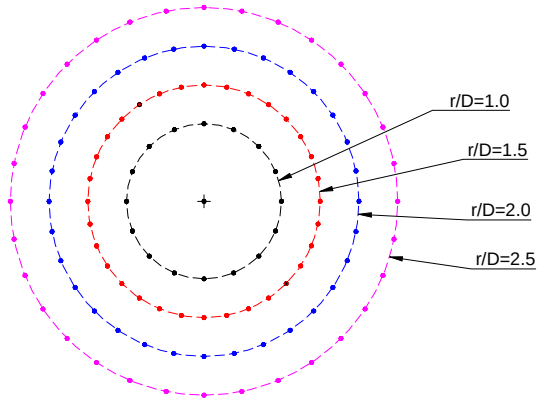
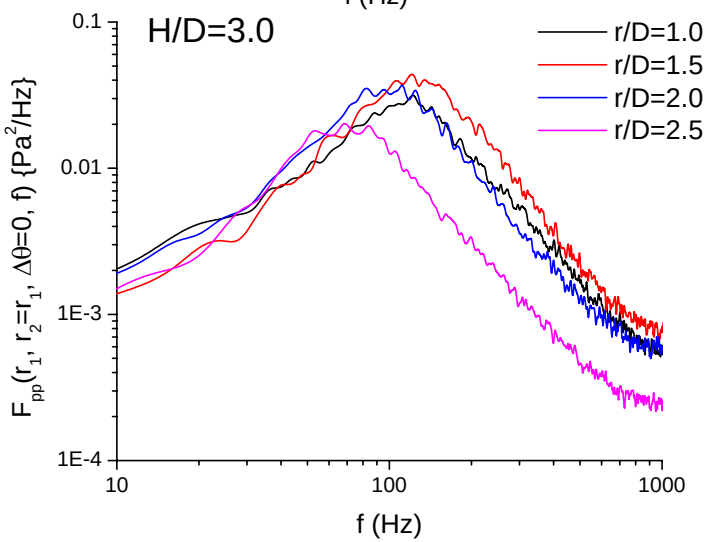
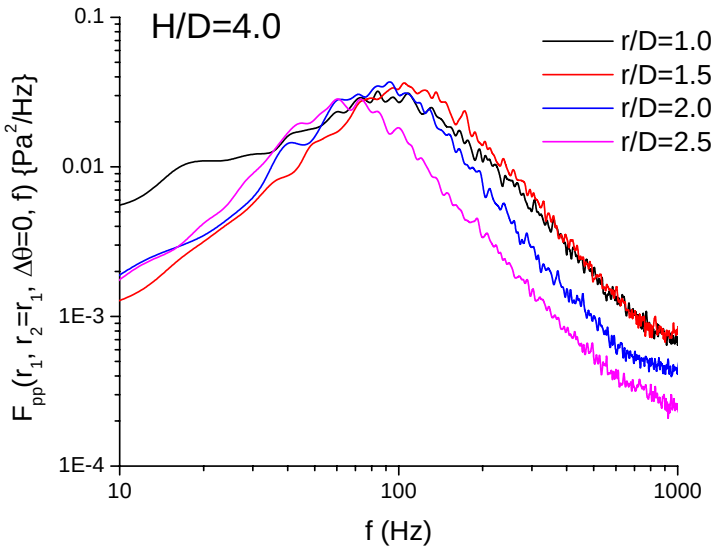
Pressure Spectra

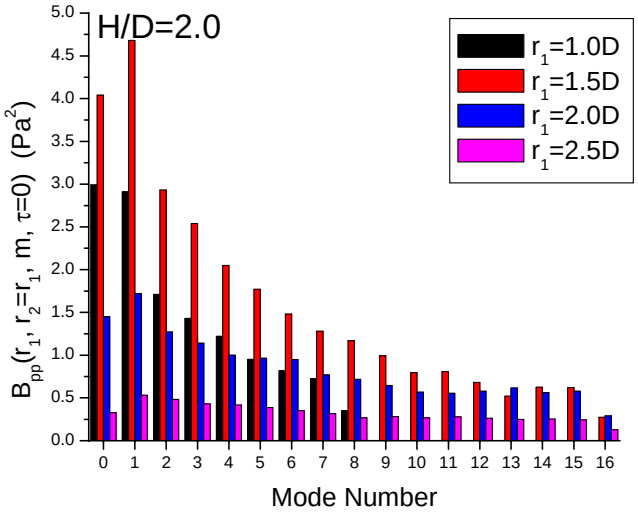


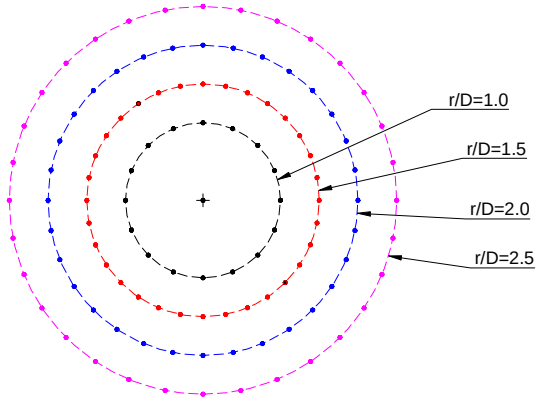


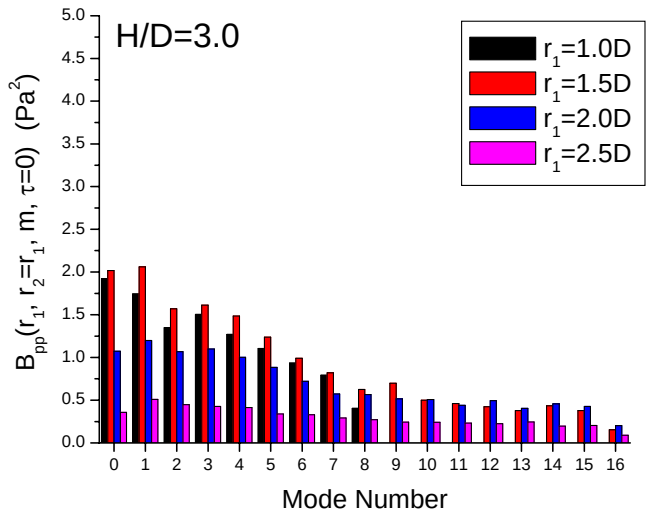


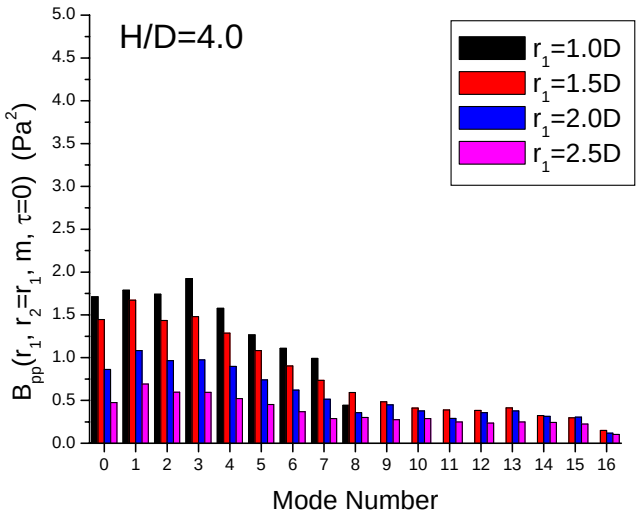


Azimuthal Spectra



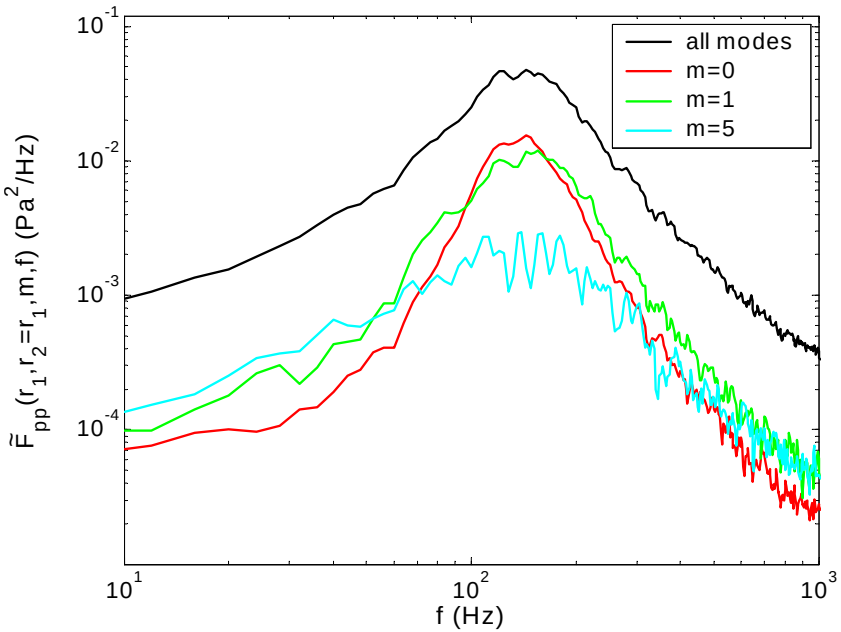




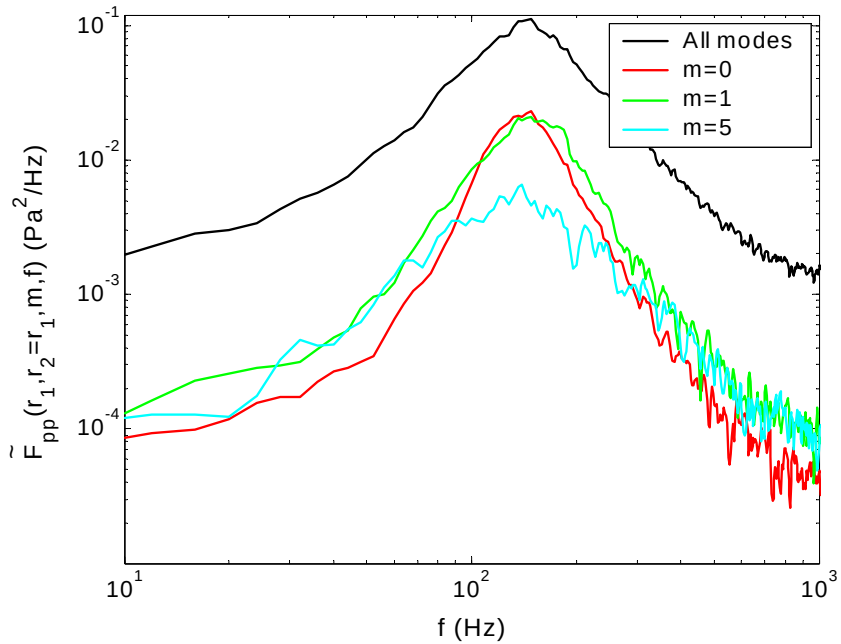


Azimuthal Frequency Spectra, H/D=2.0

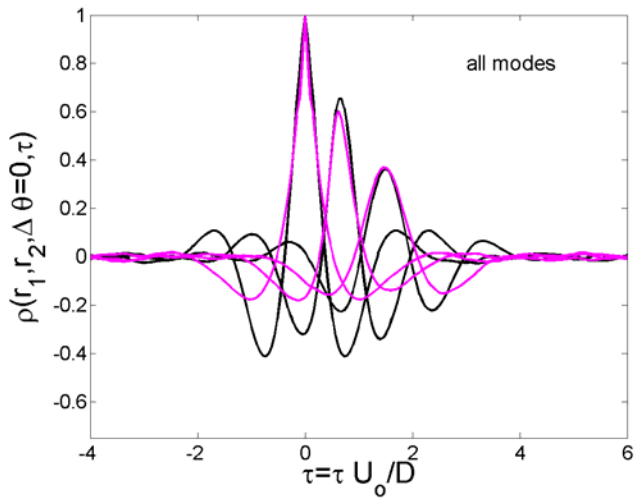
r/D=1.0

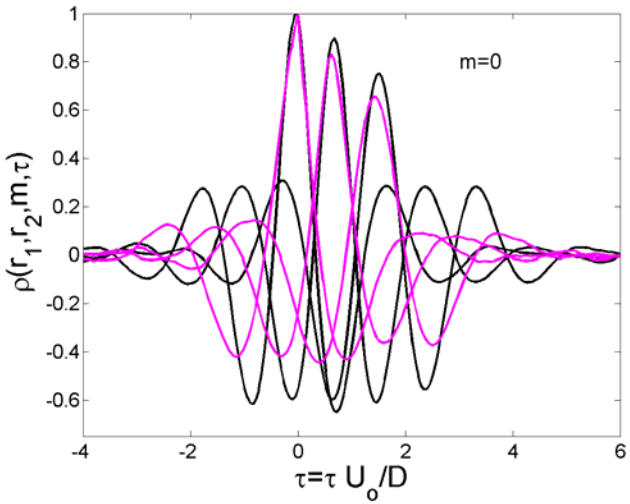


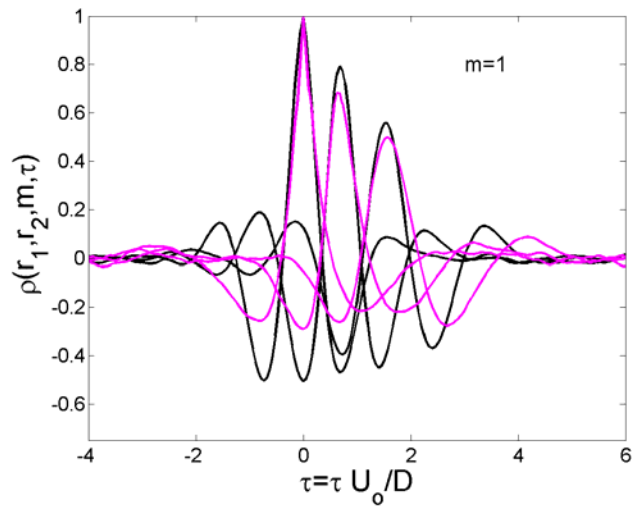
r/D=1.5

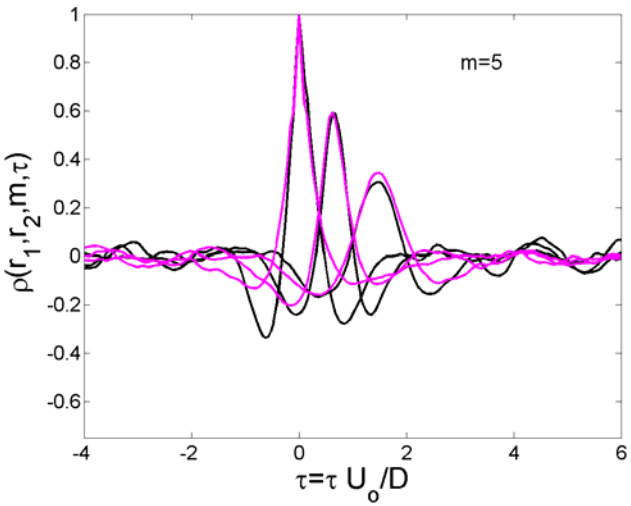


Two-Point, Two Time Correlations



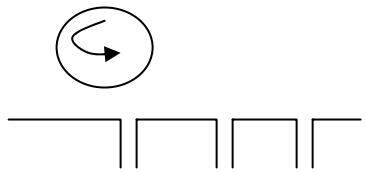






H/D=2.0

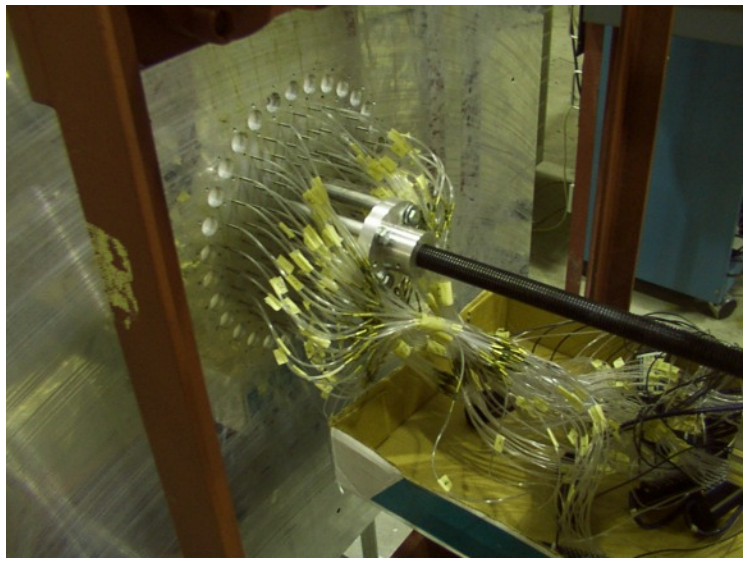
H/D=4.0



r_1/D =1.0

Dynamics of the Instantaneous Structures

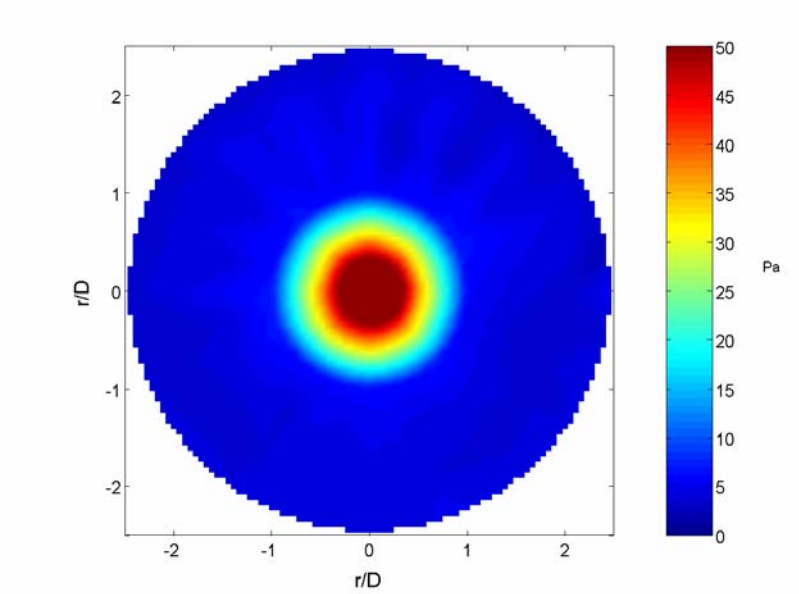
- Pressure sampled at 800Hz for 350 blocks of 400 data points
  - ESP scanner system at Boundary Layer Wind Tunnel, University of Western Ontario
  - Signals are phase corrected in post-processing



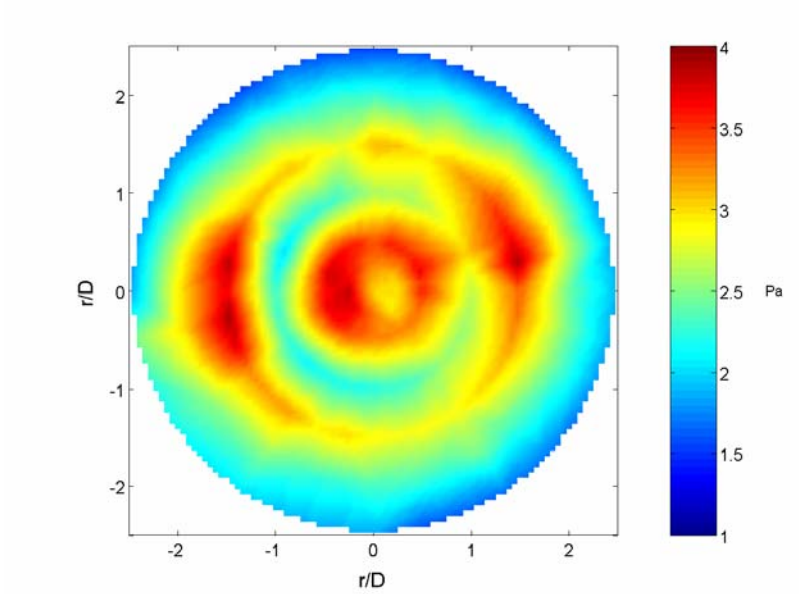
- Perform Proper Orthogonal Decomposition in Azimuthal Direction
  - Fourier Modes

Pressure Field, H/D=2.0

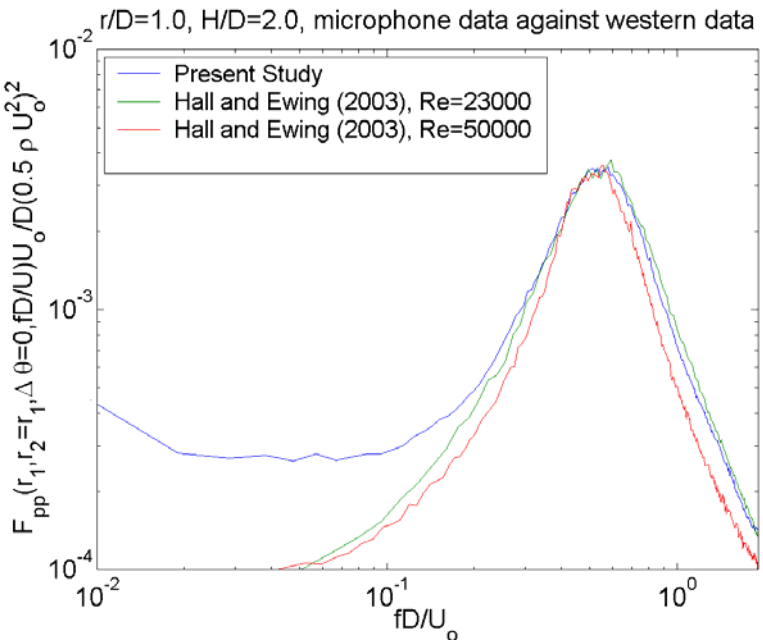
Mean Pressure

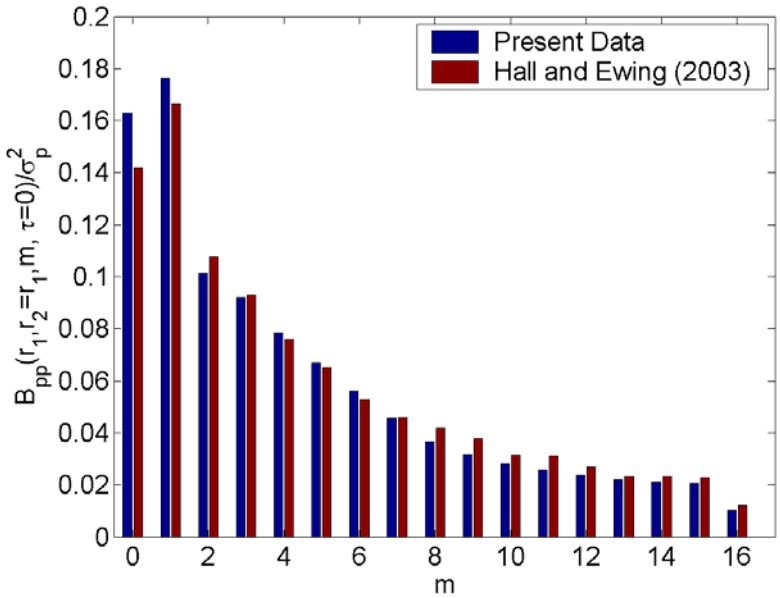


Fluctuating Pressure



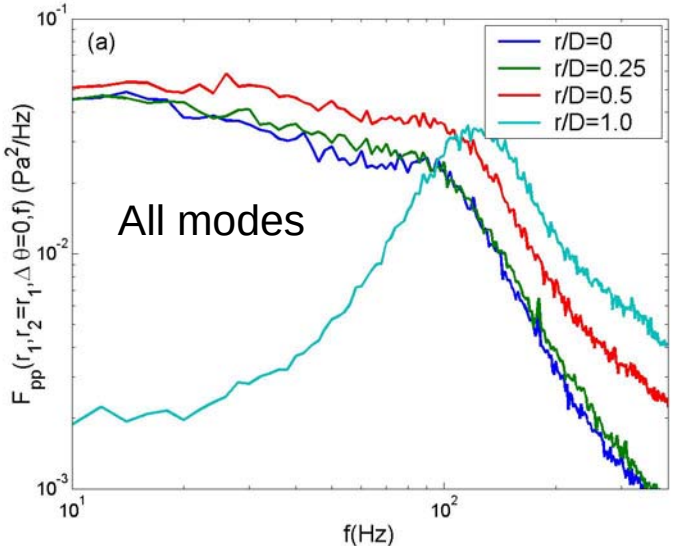
Comparison to microphone data

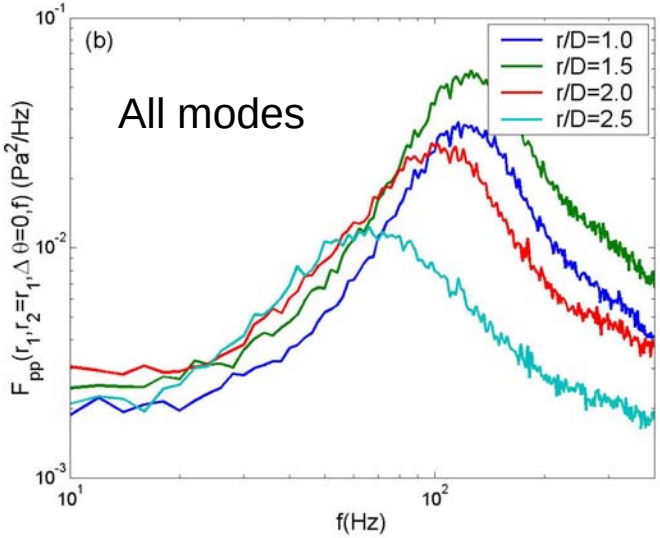


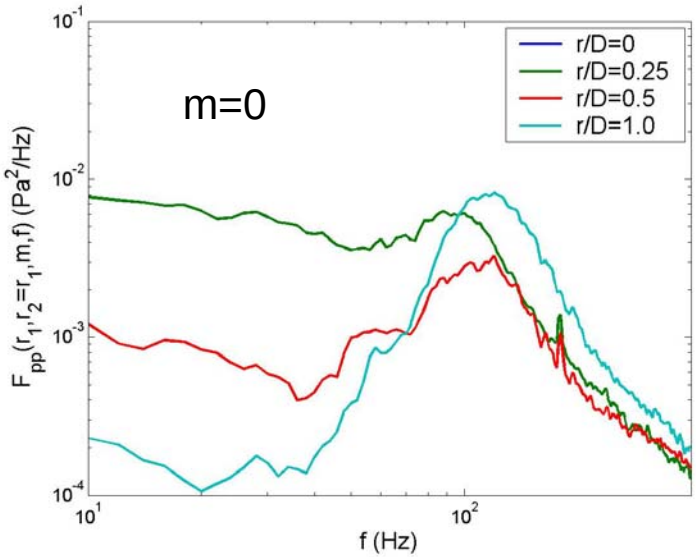


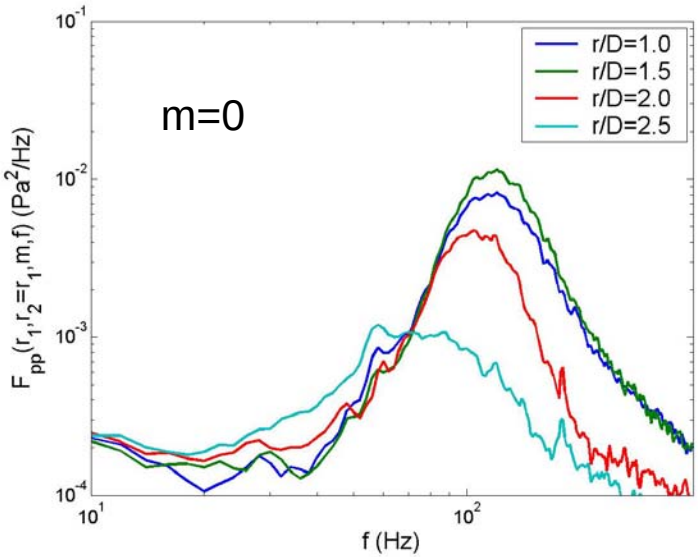
Hall et al. (2003)

Pressure Spectra



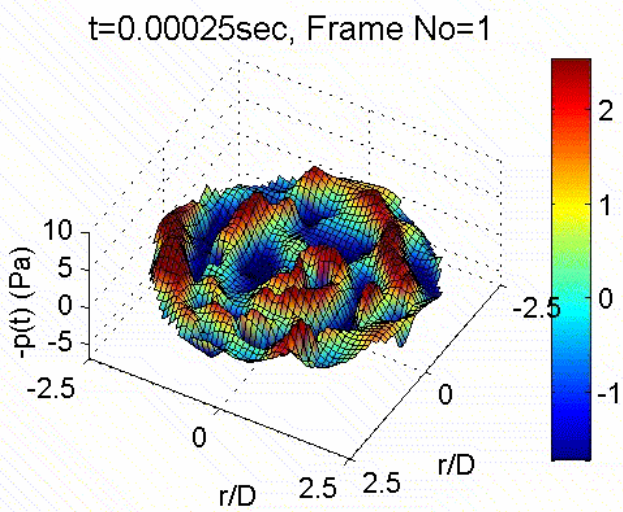


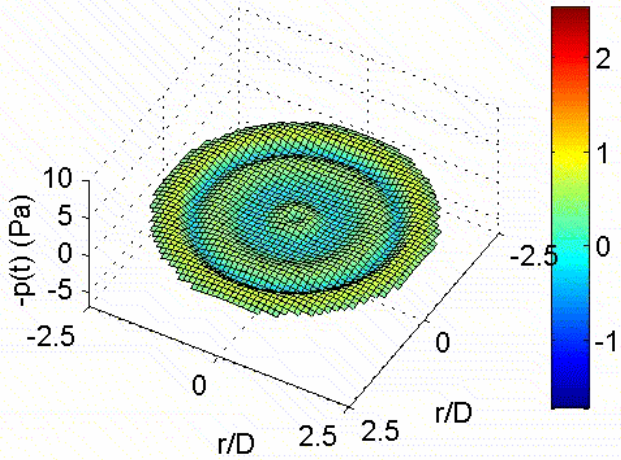




H/D=2.0

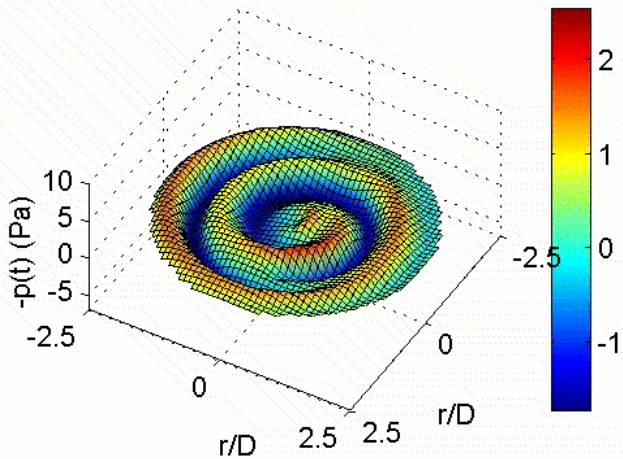
All modes





m=0

m=0, +/-1



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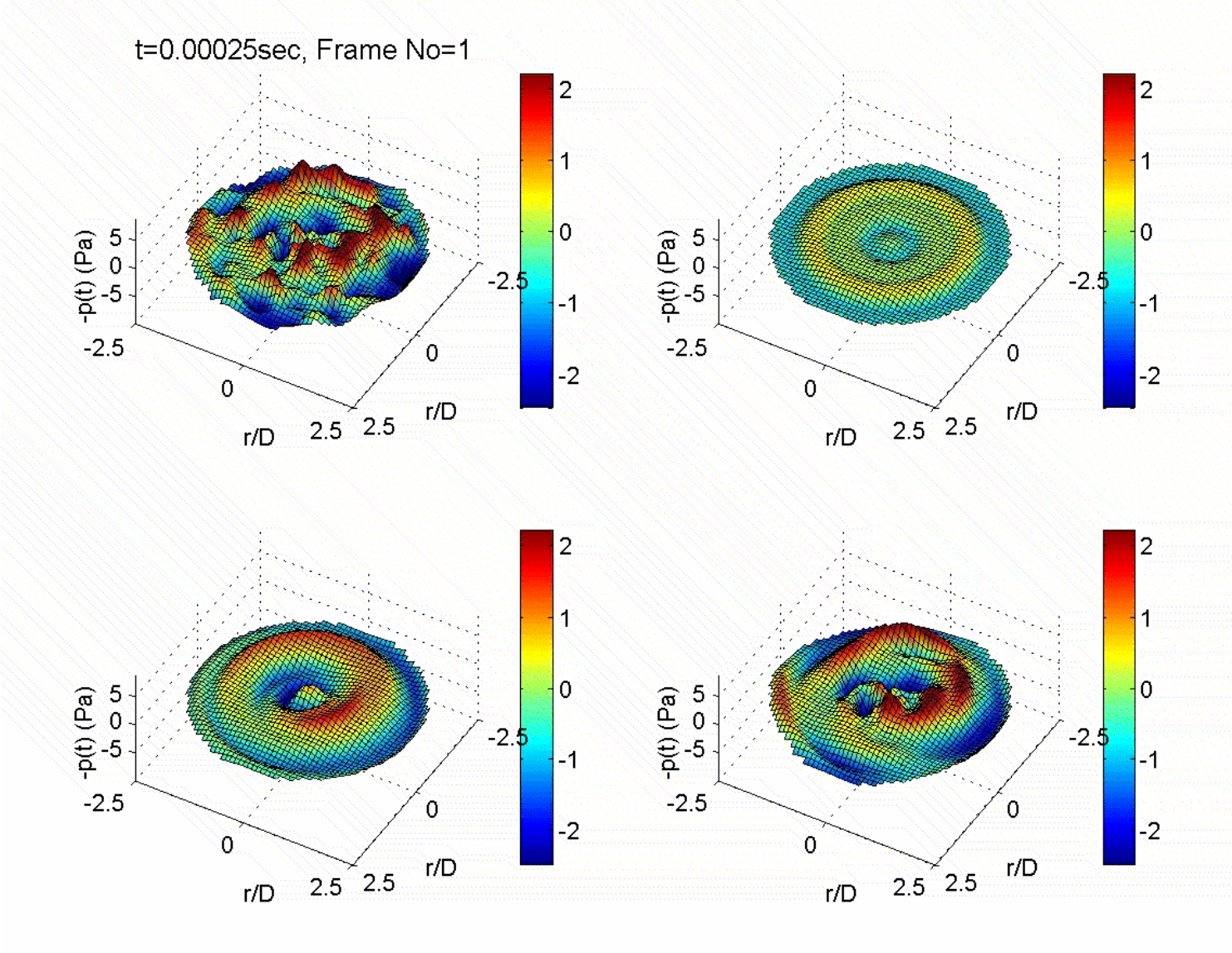
H/D=4.0

All modes



m=0

m=0, +/-1

m=0 to +/-5

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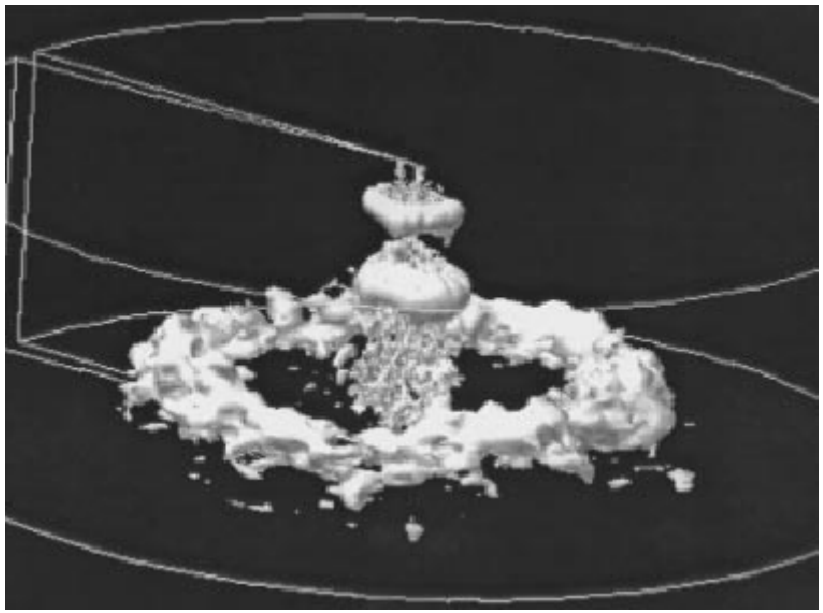
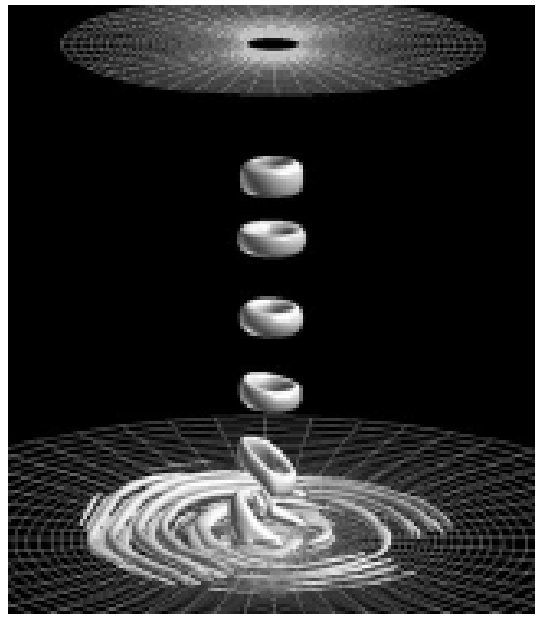
Impinging Jet DNS



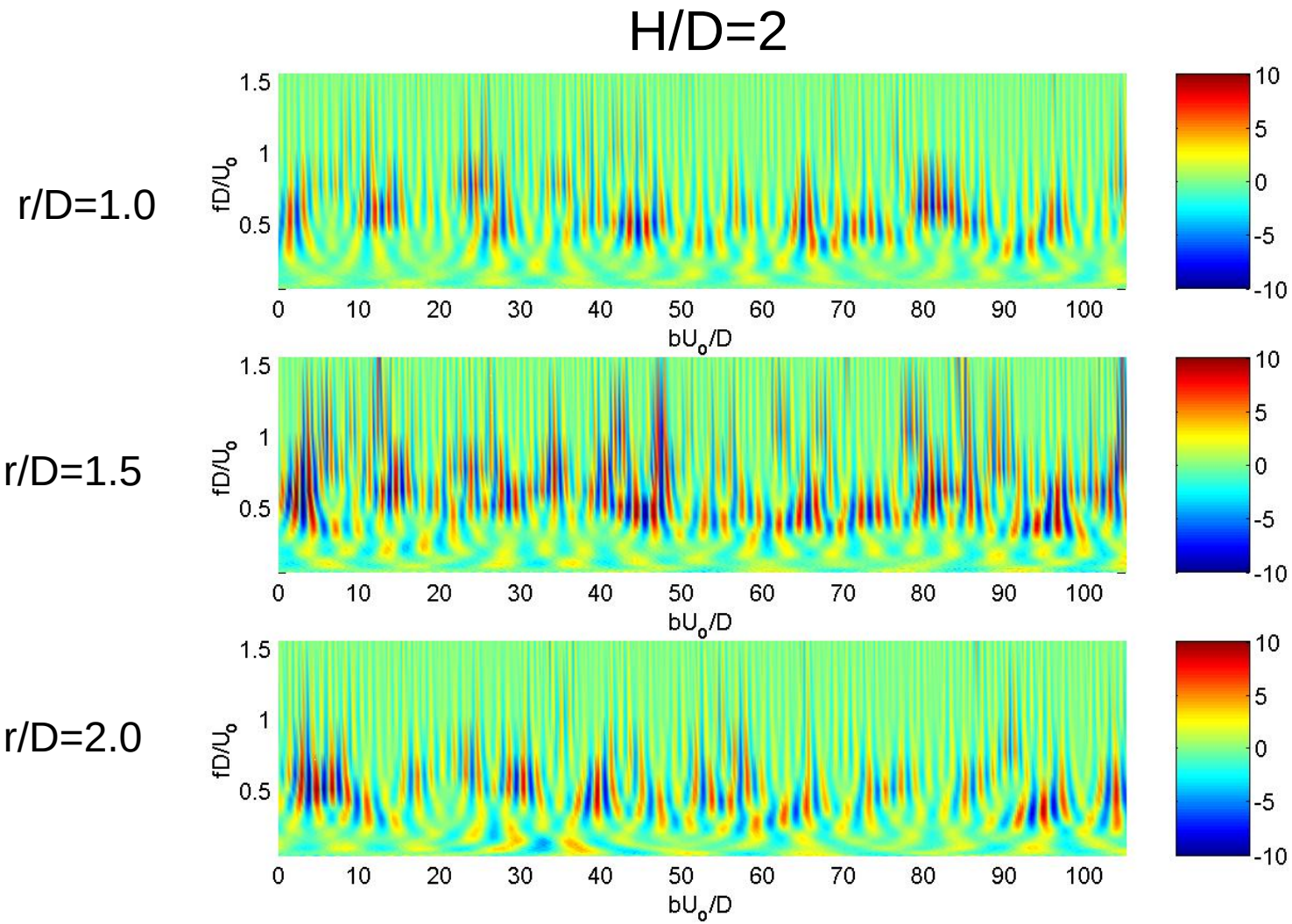
Satake and Kunugi (1998)
Re=10000
H/D = 6, Confined



Tsubokura (2003)
Re=2, 000
Forced at Strouhal Frequency
H/D = 9

Inlet Condition Fully Developed Pipe Flow

Wavelet Analysis: Instantaneous Pressure



Wavelet Analysis: Azimuthal Modes

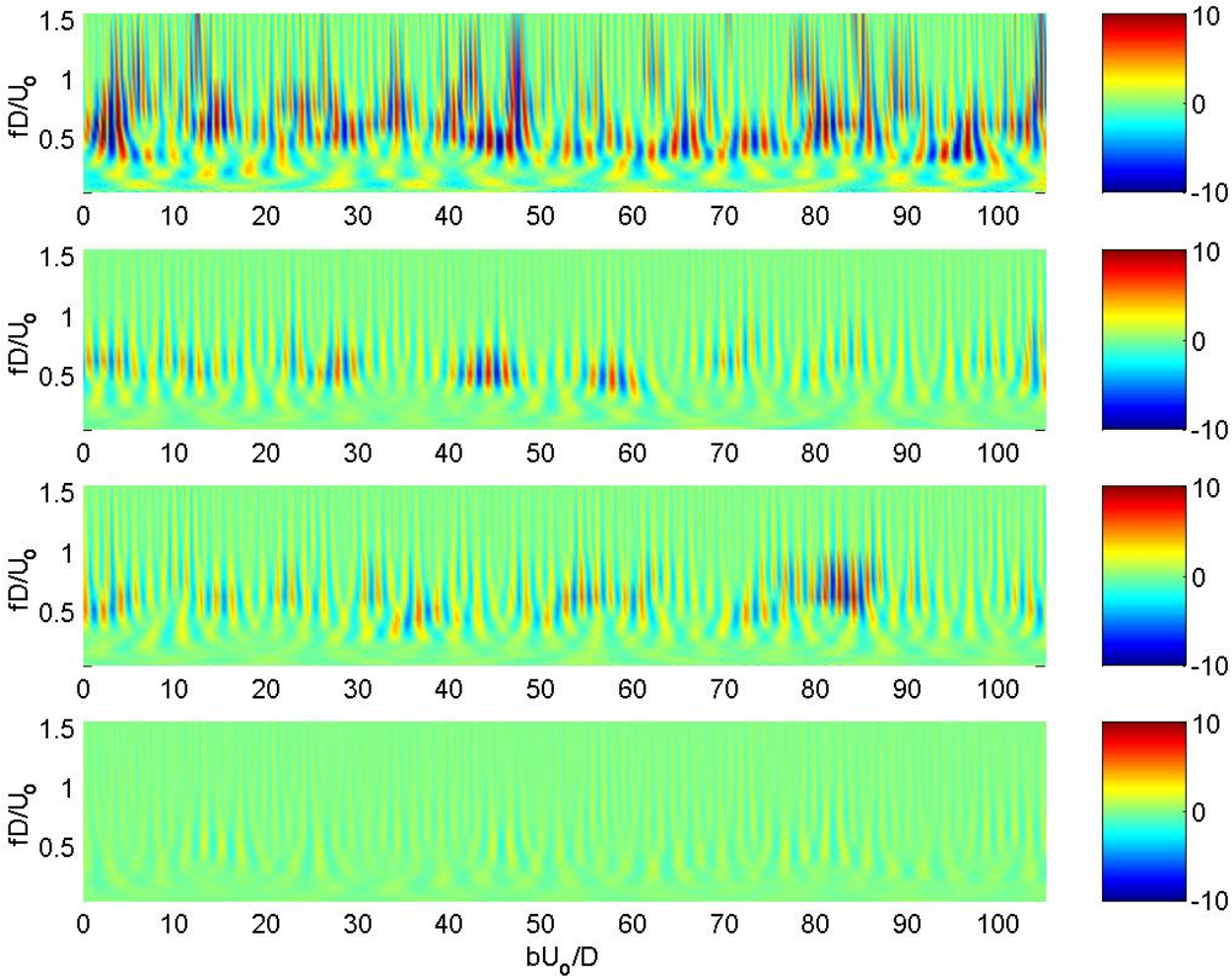
H/D =2, r/D =1.5

All modes

m=0

m=1

m=5



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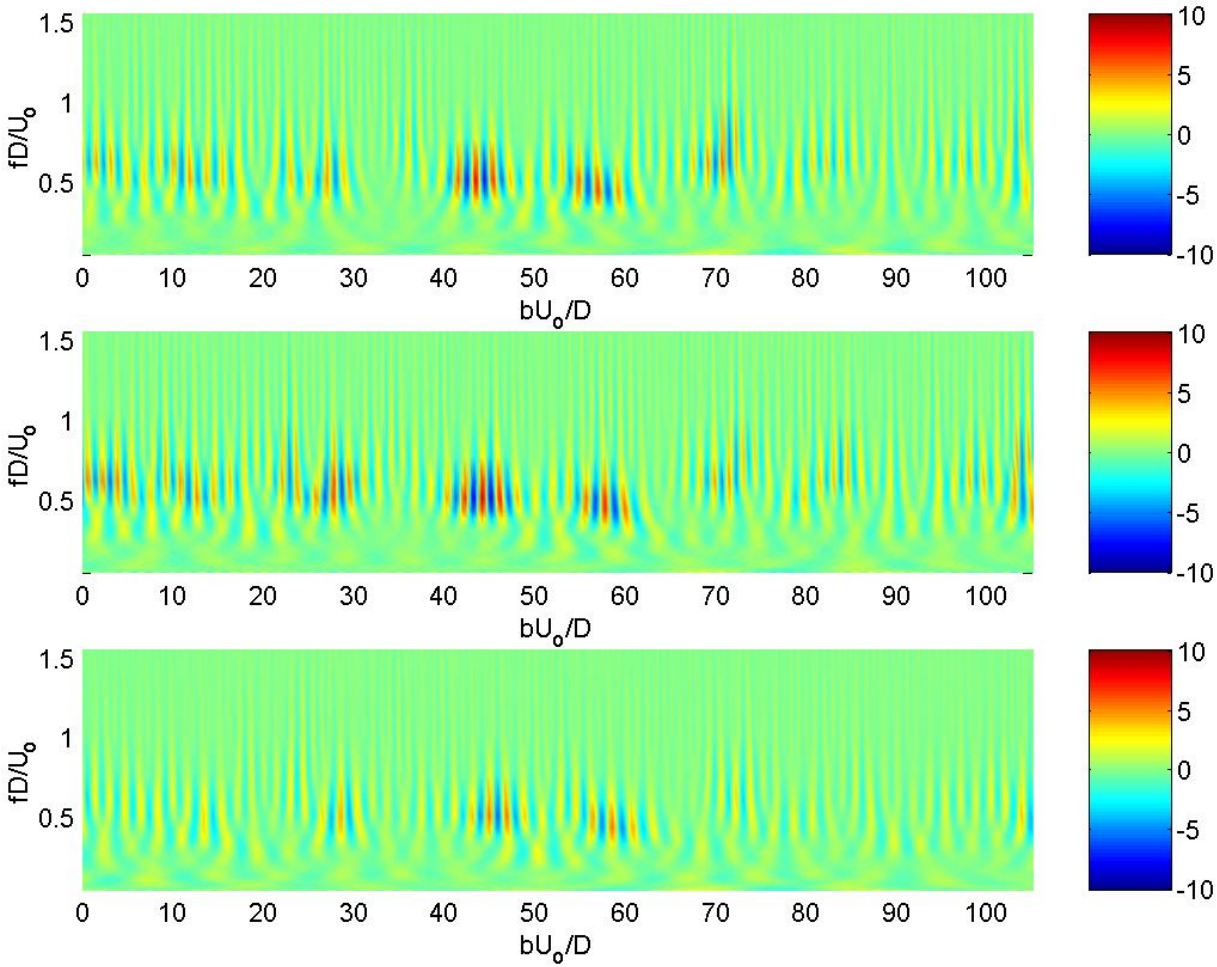
Wavelet Coefficients: Mode 0

H/D=2

r/D=1.0

r/D=1.5

r/D=2.0



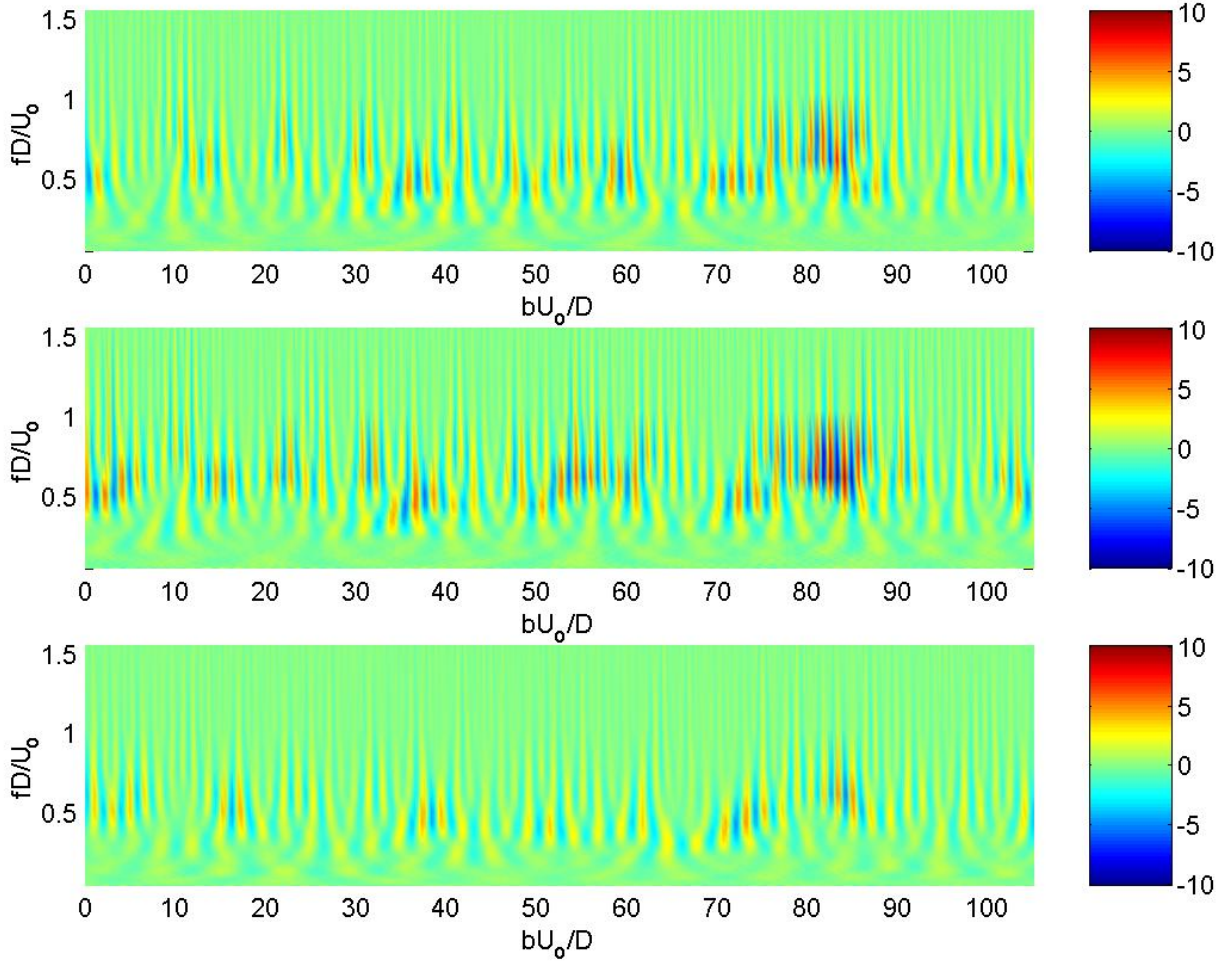
Wavelet Coefficients: Mode 1

H/D=2

r/D=1.0

r/D=1.5

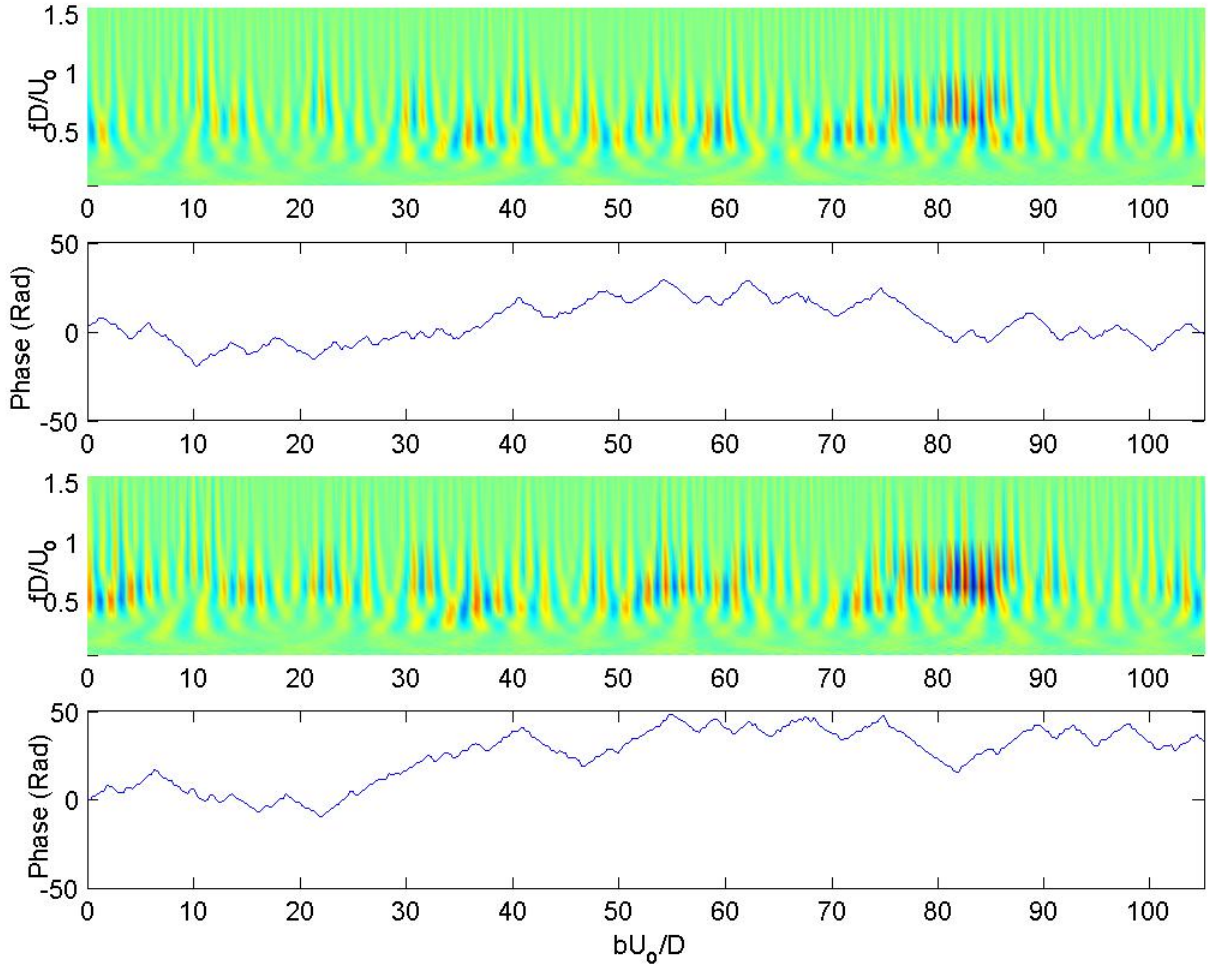
r/D=2.0



Azimuthal Mode 1: Precessing?

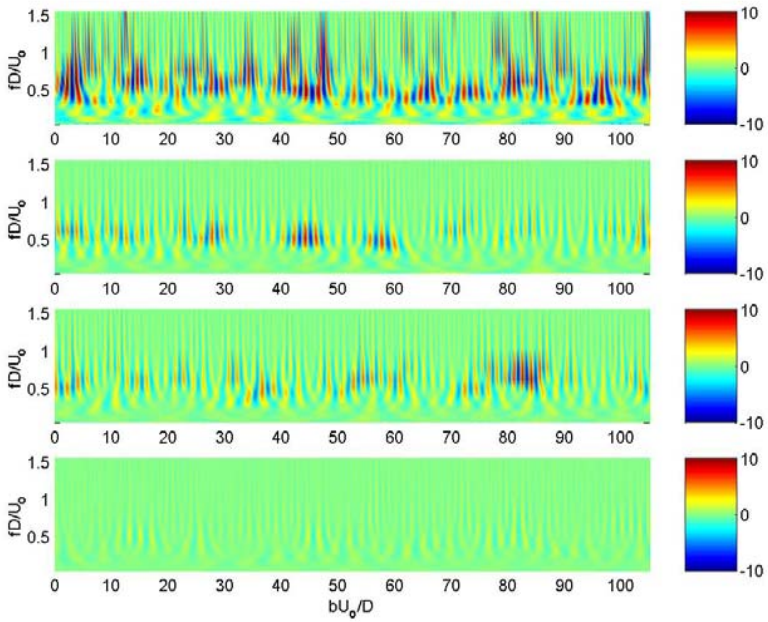
r/D=1.0

r/D=1.5



Wavelet Analysis: Effect of H/D

H/D =2, r/D =1.5



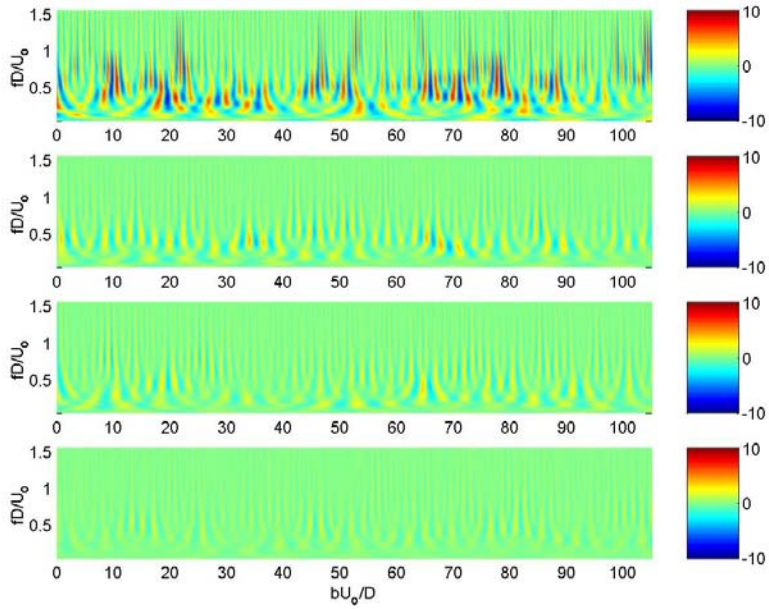
All modes

m=0

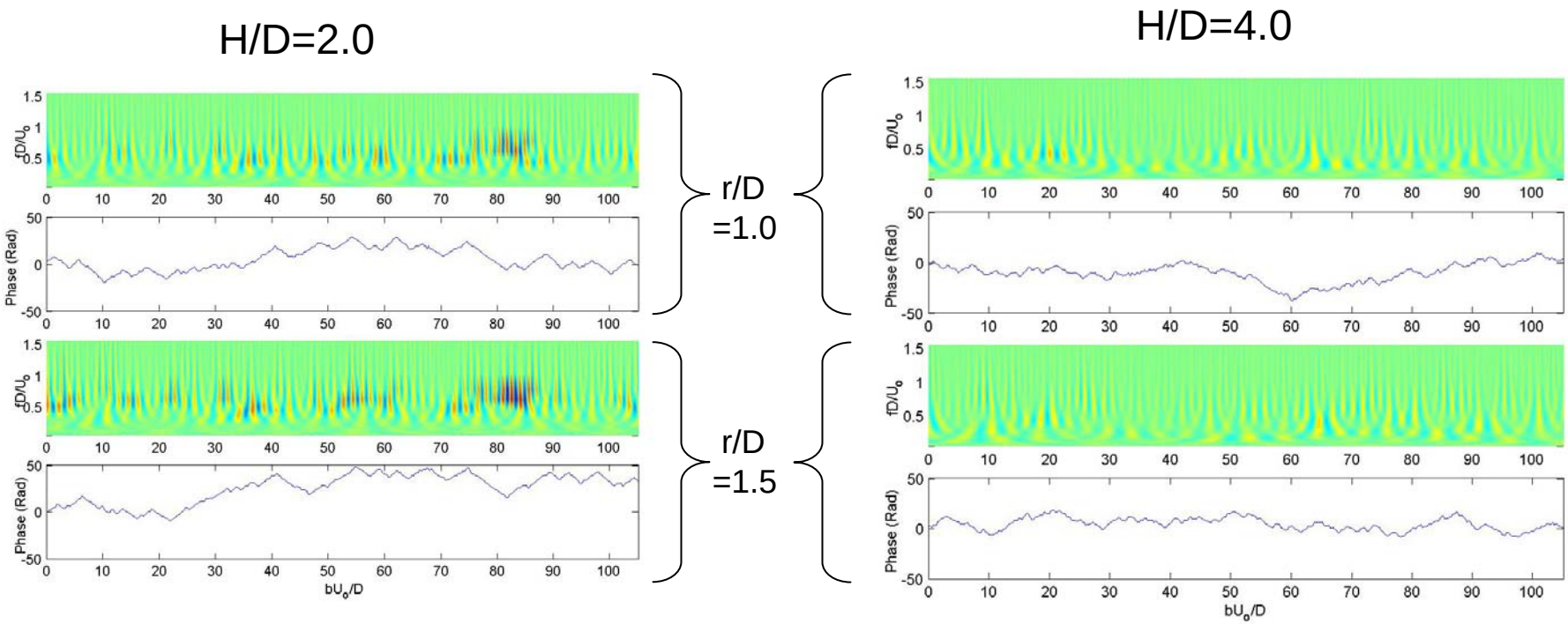
m=1

m=5

H/D =4, r/D =1.5



Wavelet Analysis: Effect of H/D



Concluding Remarks

- Measurements of the instantaneous wall pressure fluctuations were used to examine the development of the large-scale structures in the near field of the radial wall jet.
- The inclusion of at least azimuthal mode 1 was necessary to reasonable model the dynamics of the flow.
- Contributions from azimuthal mode 0 and 1 underwent variations in magnitude that persisted over periods corresponding to the passage of several structures.
- There were extended periods where the slope of the phase of mode 1 was linear suggesting there may be periods of jet precessing of varying duration and direction.
- Structures contributing to fluctuating wall pressure did not appear to become significantly more intermittent as H/D increased.
- There was less systematic variation of the phase of mode 1 as H/D increased suggesting less systematic jet precessing.