

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) June 2014		2. REPORT TYPE Briefing Charts		3. DATES COVERED (From - To) June 2014- July 2014	
4. TITLE AND SUBTITLE Near-Wall Velocity Field Measurements of a Very Low Momentum Flux Transverse Jet				5a. CONTRACT NUMBER In-House	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Salazar, Forliti, Kuzmich, Coy				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER Q09Z	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/RQRC 10 E. Saturn Blvd Edwards AFB CA 93524-7680				8. PERFORMING ORGANIZATION REPORT NO.	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/RQR 5 Pollux Drive. Edwards AFB CA 93524-7048				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-RQ-ED-VG-2014-220	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A: Approved for Public Release; Distribution Unlimited					
13. SUPPLEMENTARY NOTES Briefing Charts presented at 50th AIAA/ASME/ASE/ASEE Joint Propulsion Conference, Cleveland, OH, 28-30 July 2014. PA#14371					
14. ABSTRACT N/A					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 30	19a. NAME OF RESPONSIBLE PERSON Nils Sedano
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NO (include area code) 661-275-5972



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Near-Wall Velocity Field Measurements of a Very Low Momentum Flux Transverse Jet

**50th AIAA/ASME/SAE/ASEE
Joint Propulsion Conference
Cleveland, OH**

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David Forliti, Sierra Lobo, Inc.
Kayla Kuzmich, AFRL/RQRC
Edward Coy, AFRL/RQRC**

Public Affairs Clearance number xxxx

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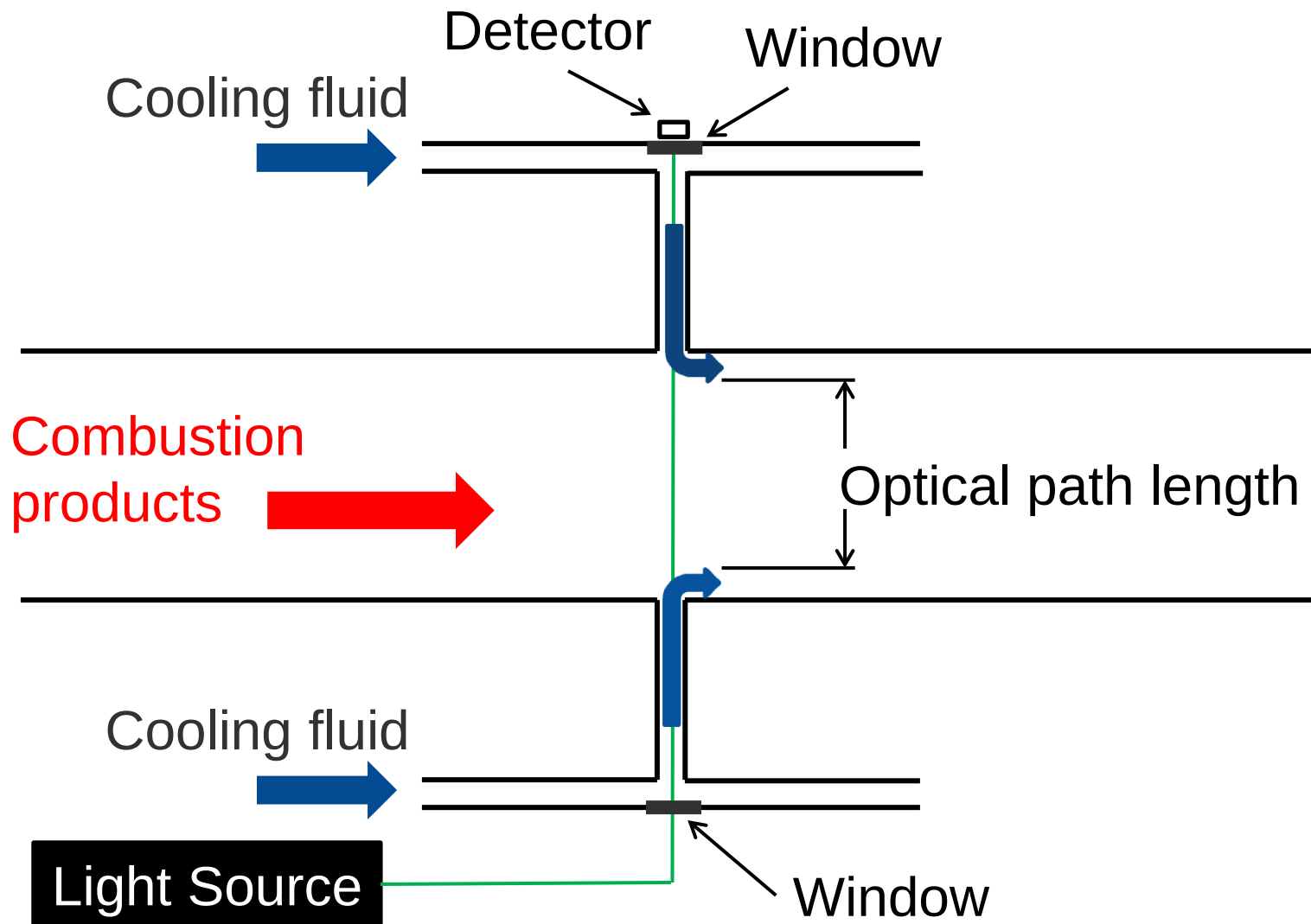
Outline



- **Research Motivation**
- **Experimental Setup**
- **Results**
- **Conclusion**

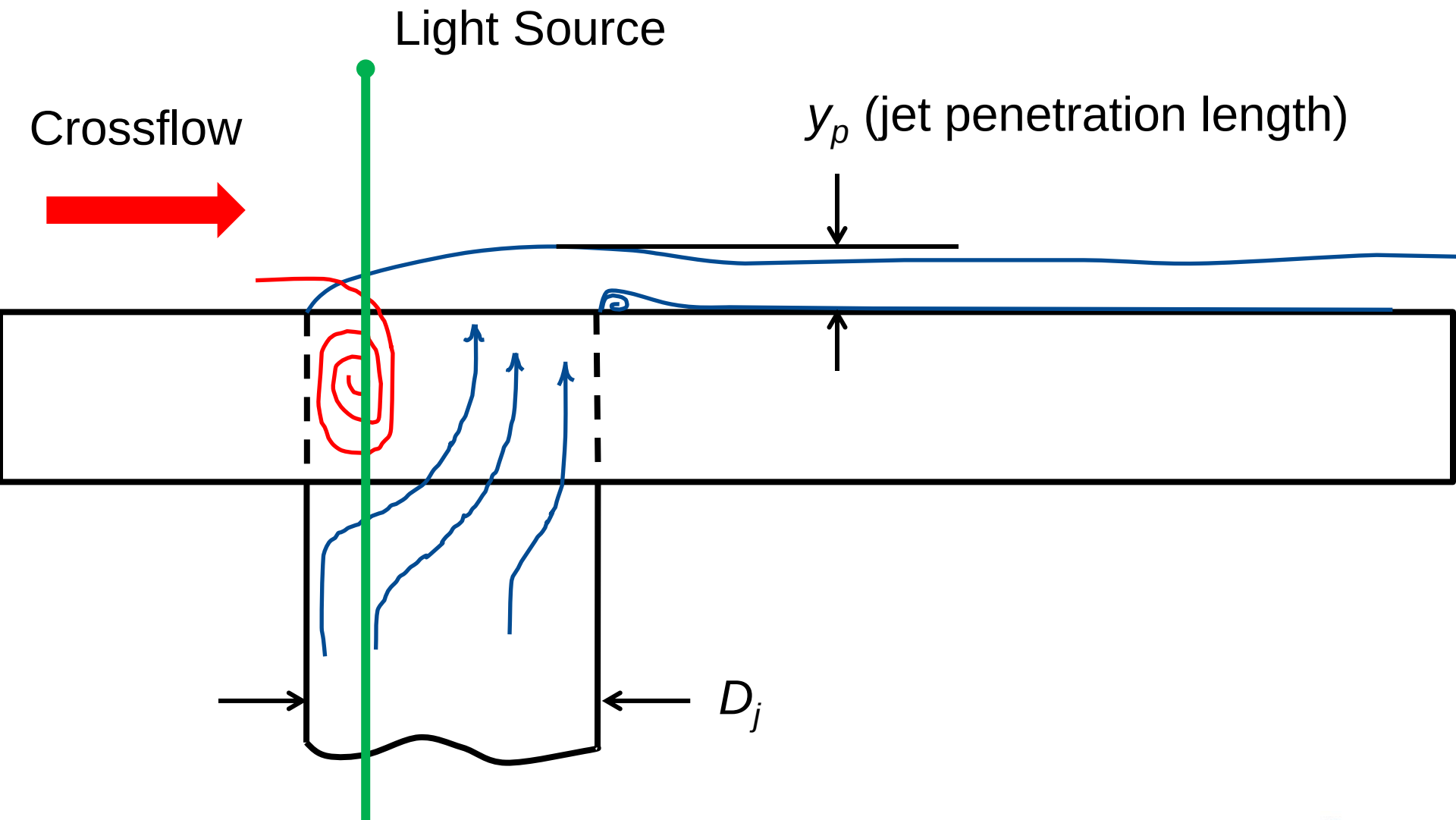


Optical Diagnostics



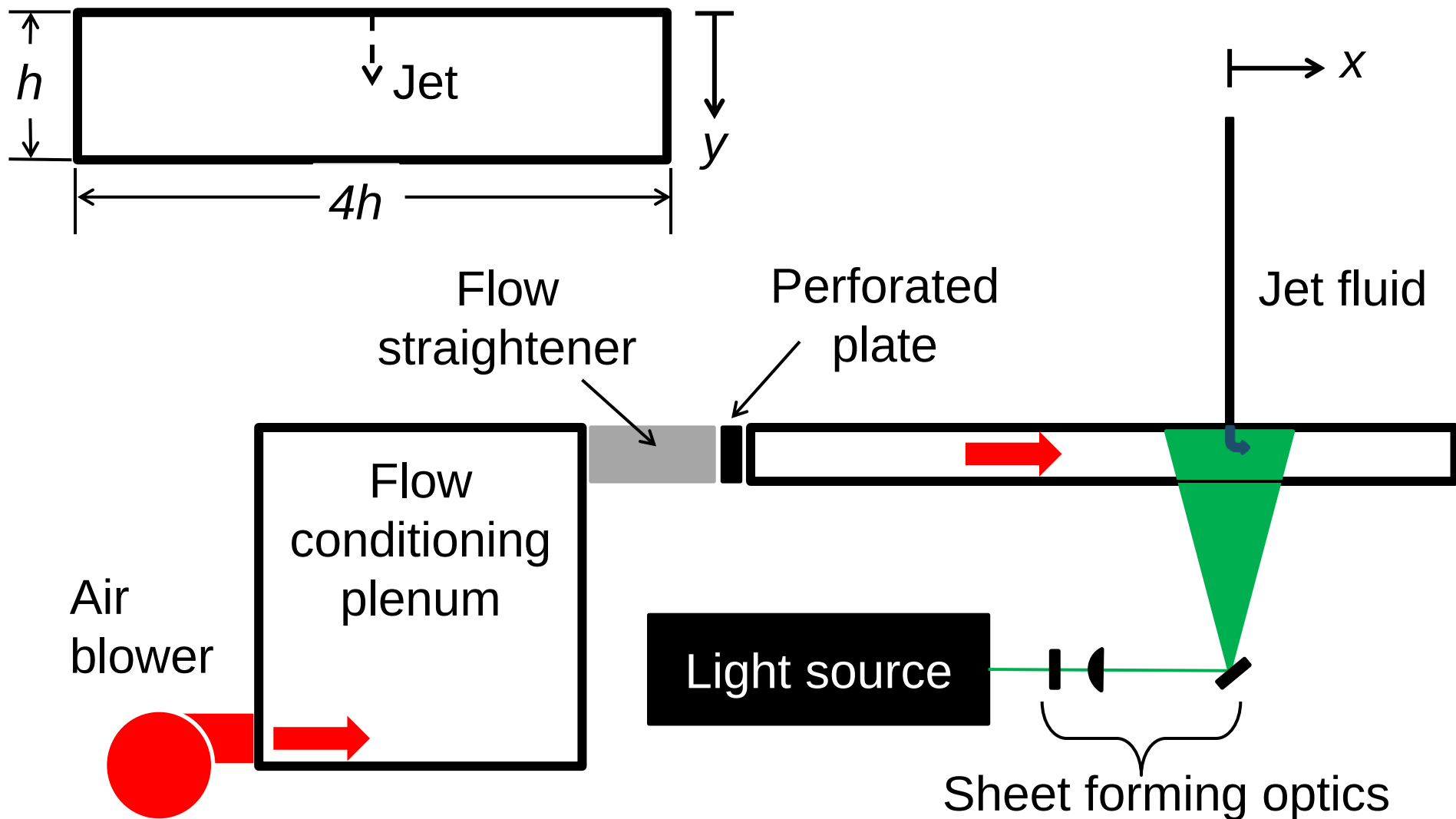


Jet and Crossflow Interaction





Experimental Facility

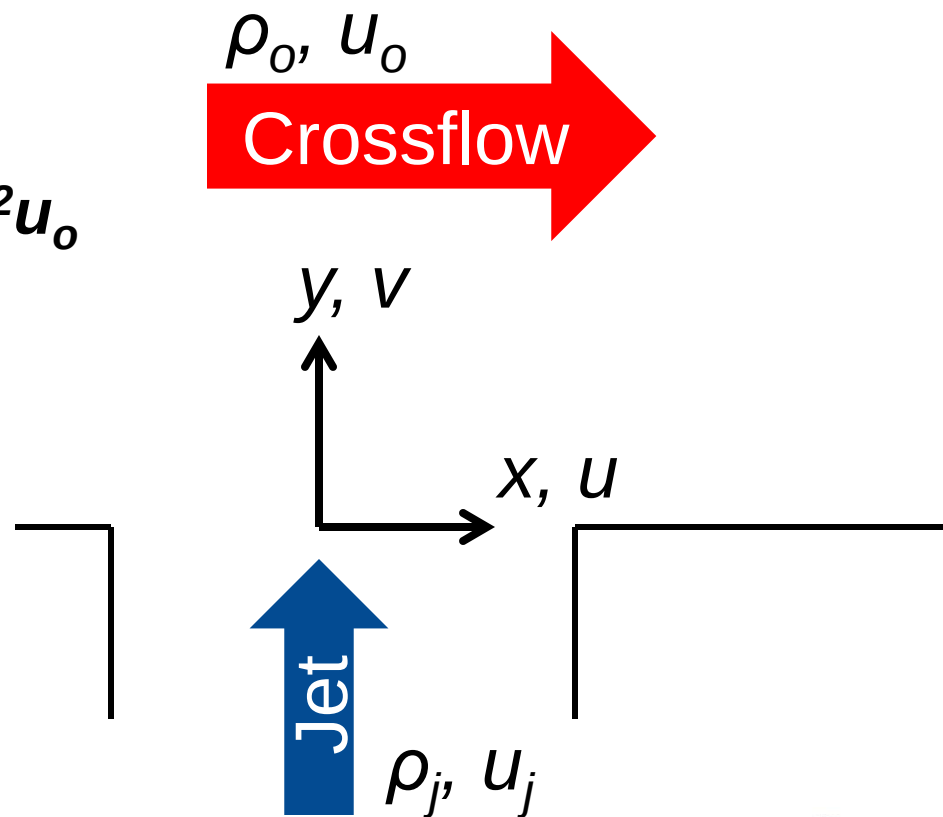




Important Parameters



- Momentum flux ratio
 - $J = \rho_j u_j^2 / \rho_o u_o^2$
- Blowing ratio
 - $M = J^{1/2} = \rho_j^{1/2} u_j / \rho_o^{1/2} u_o$

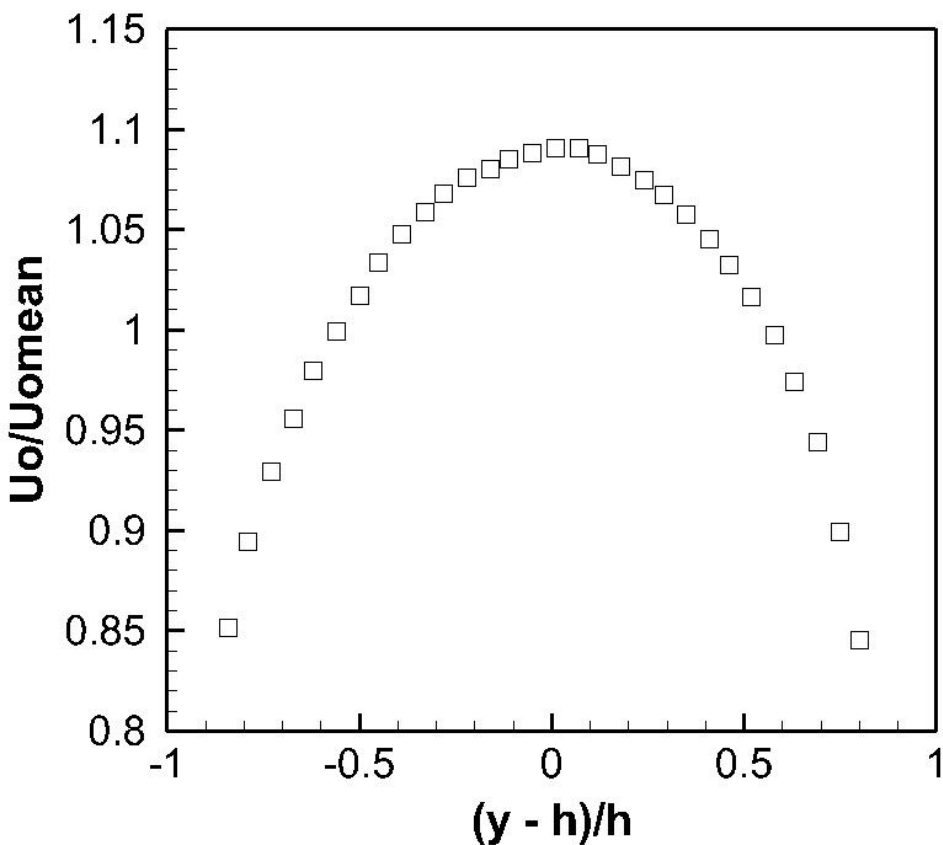




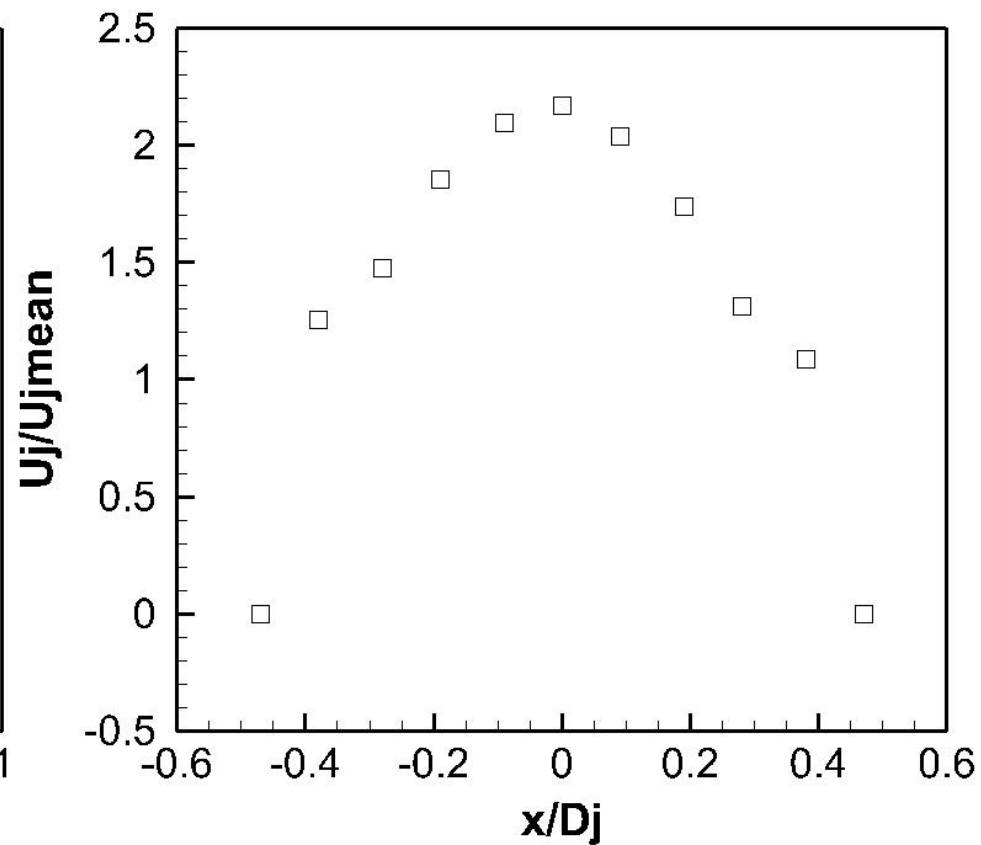
Initial Conditions



Crossflow



Jet

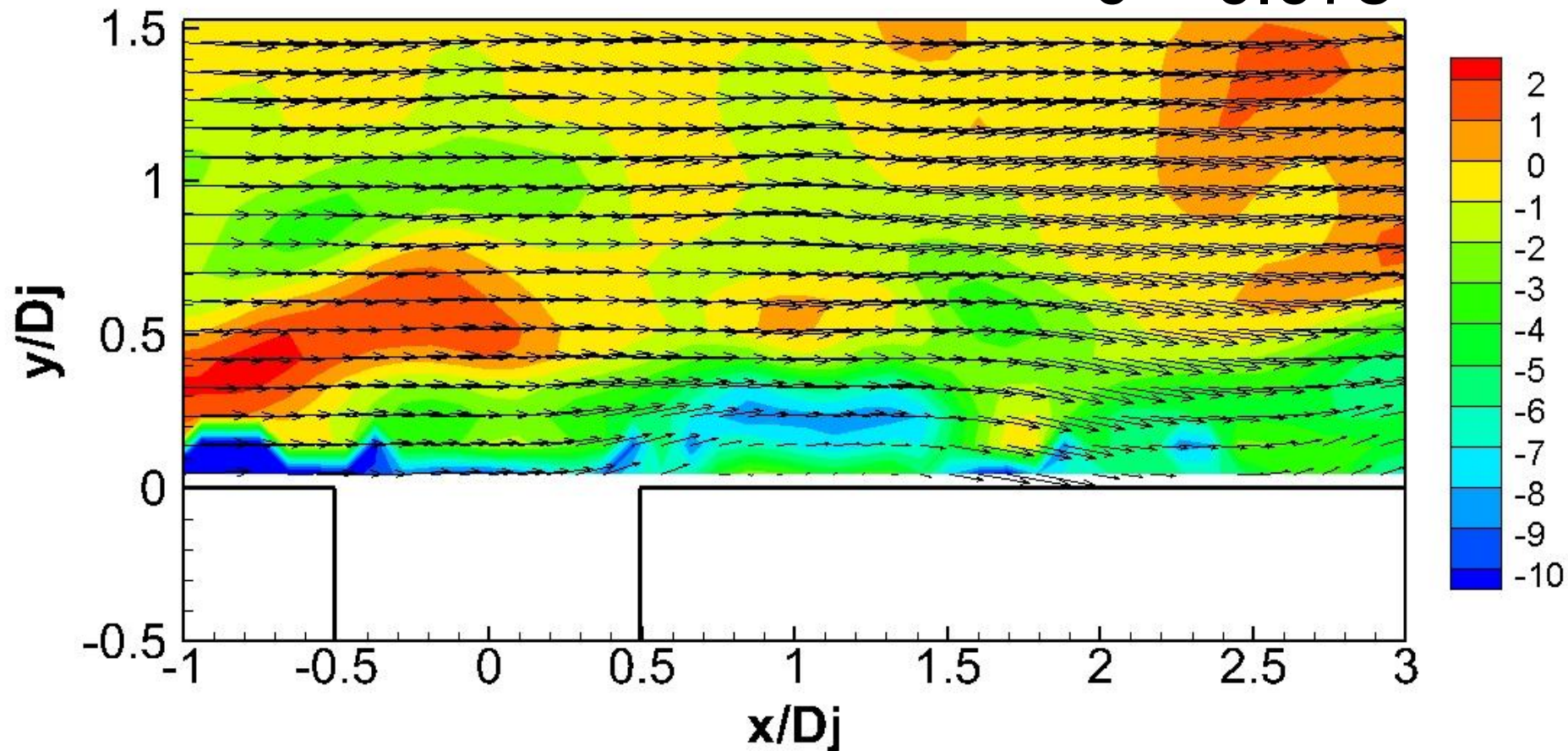




Instantaneous Velocity Field

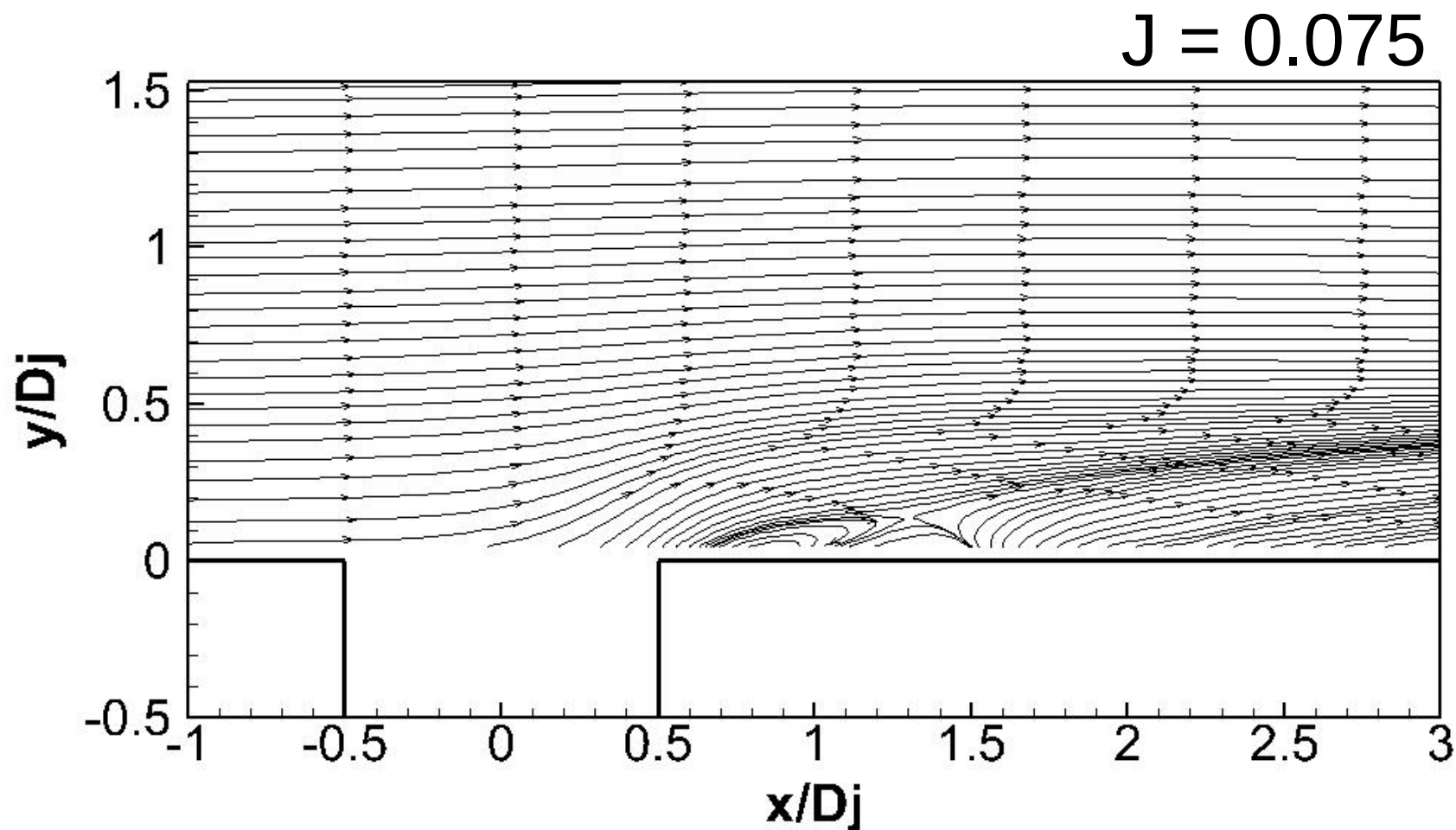


$J = 0.075$



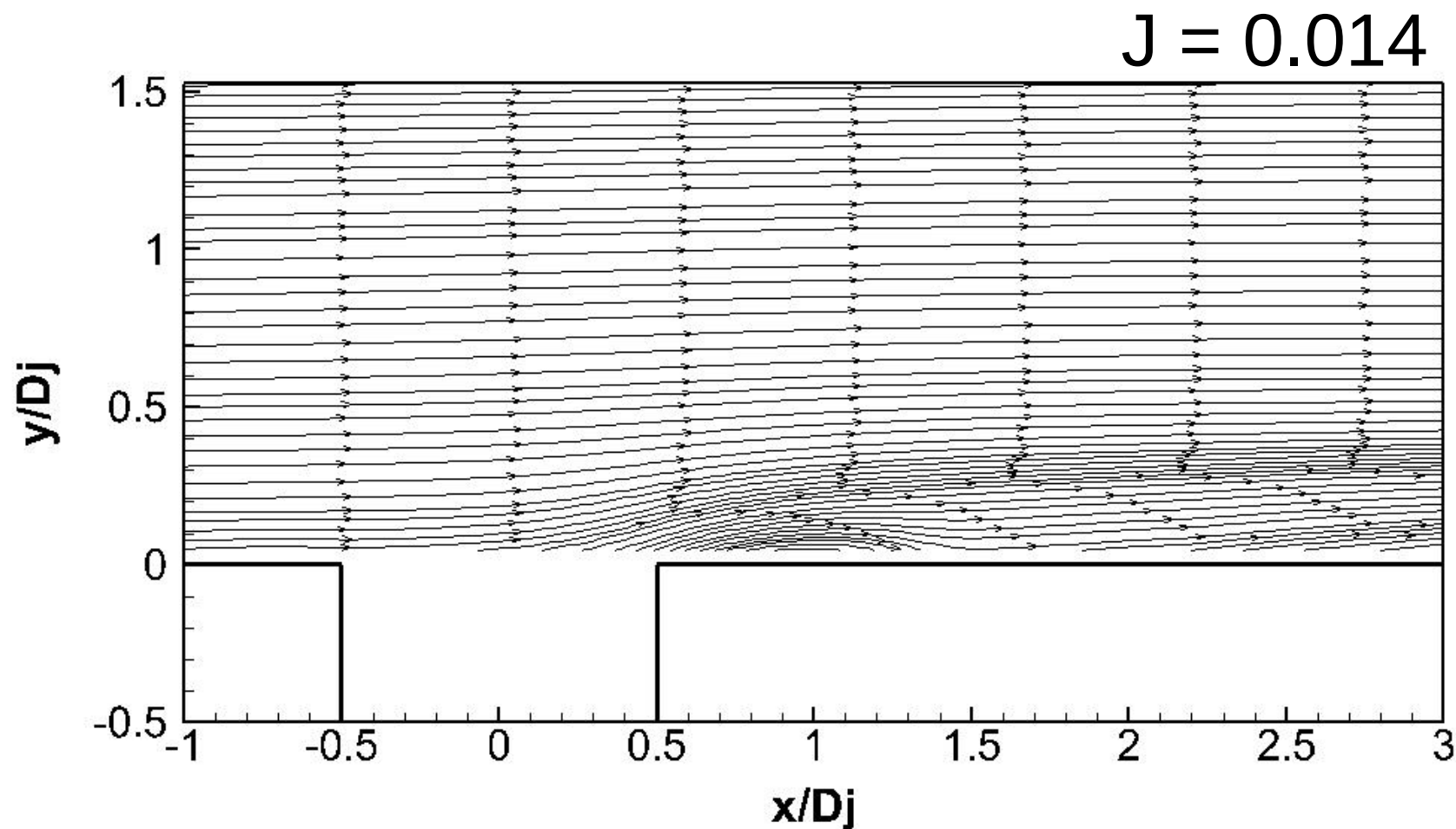


Mean Velocity Field – Streamlines





Mean Velocity Field – Streamlines

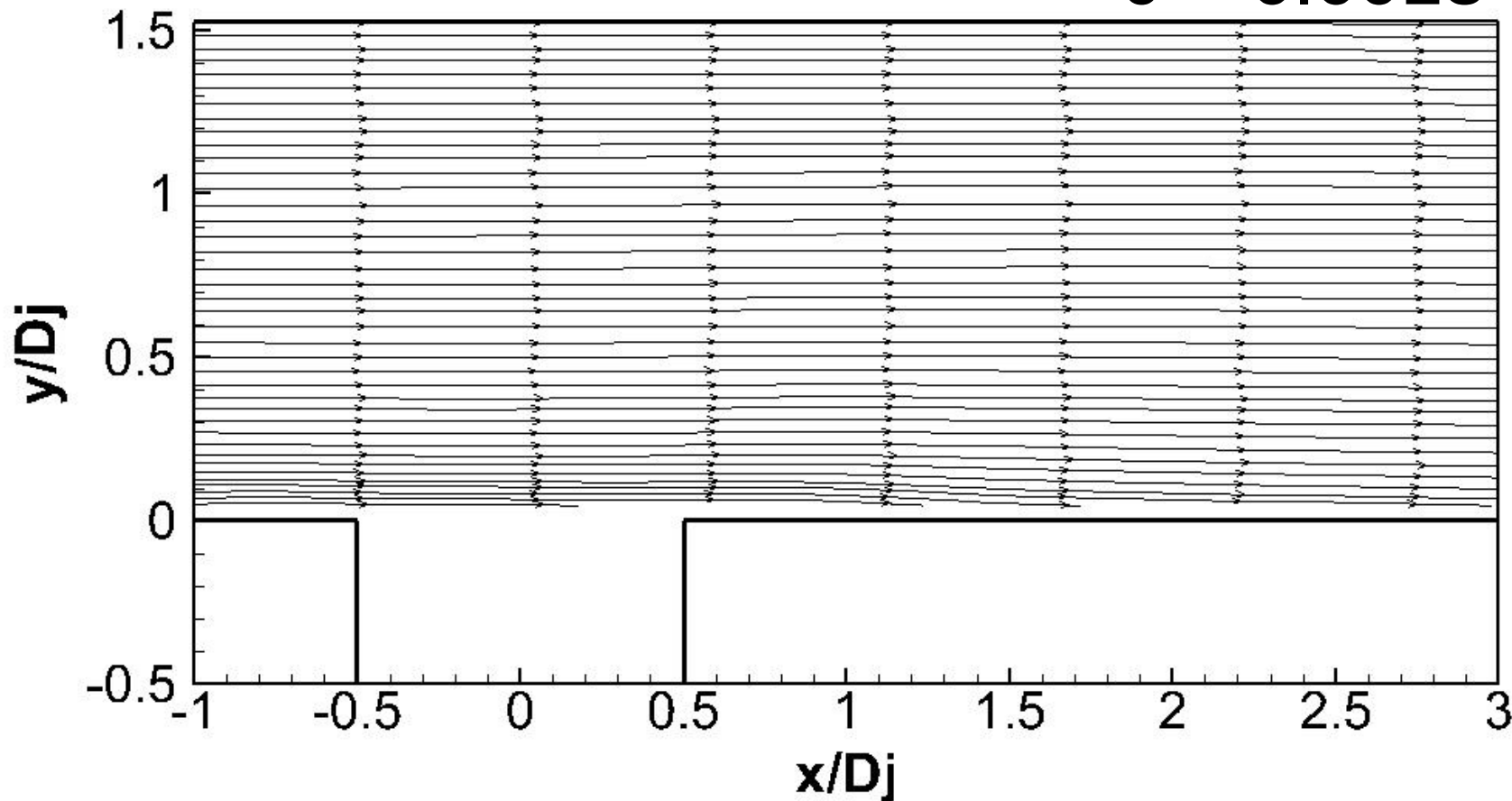




Mean Velocity Field – Streamlines

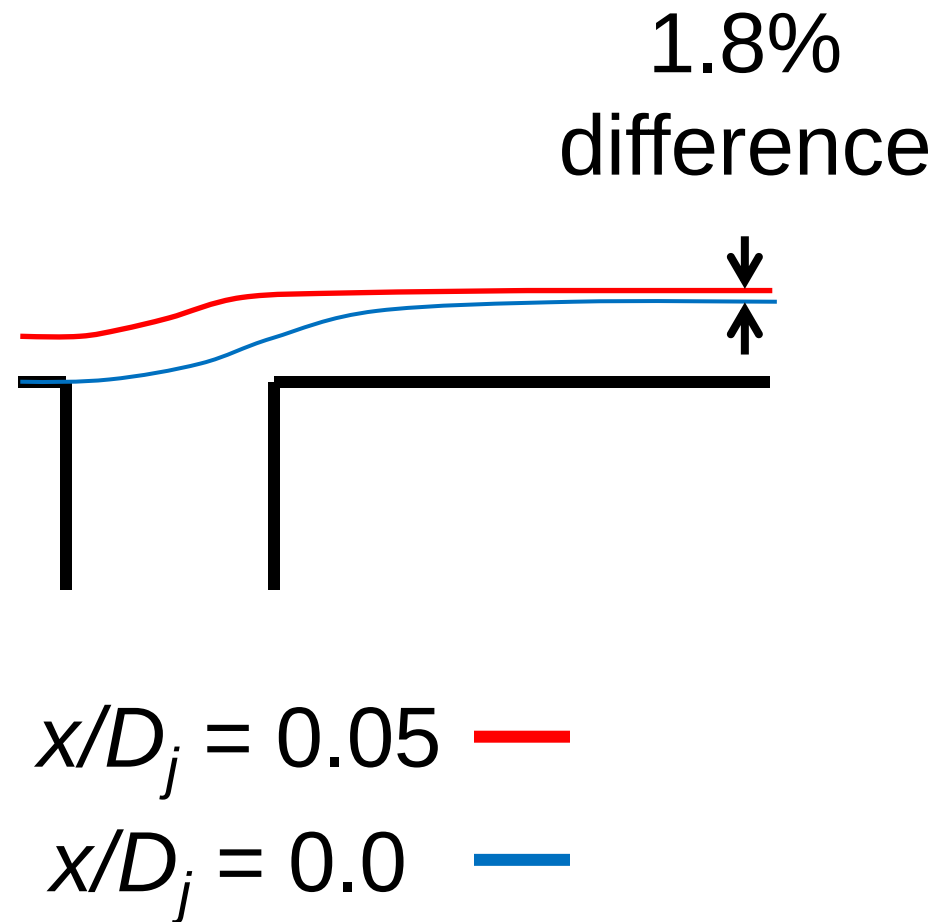
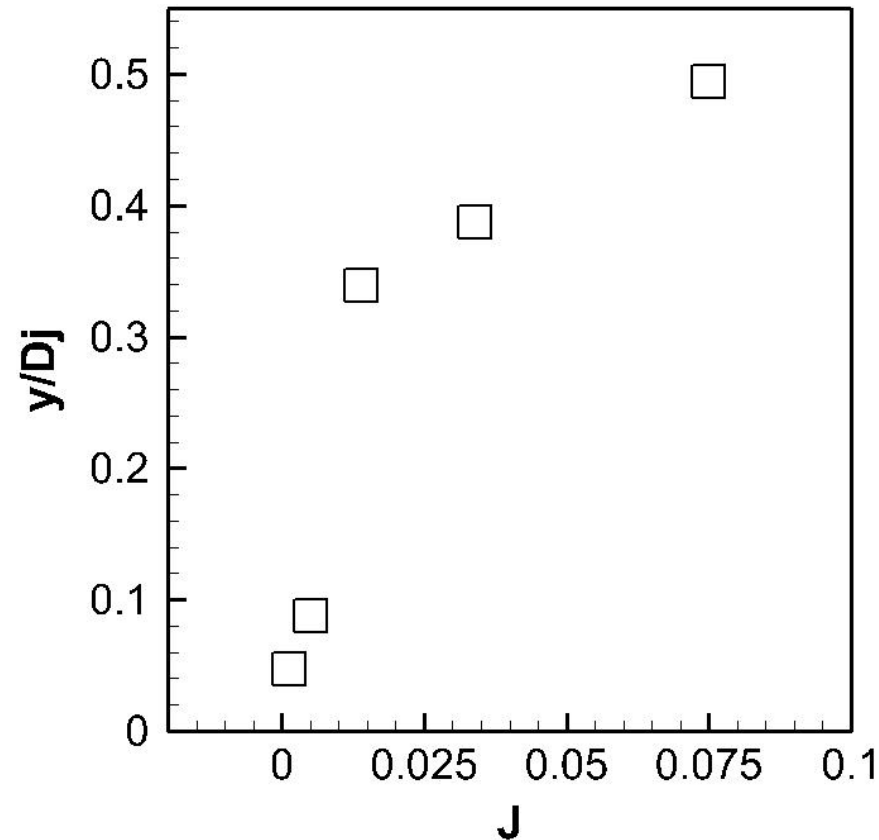


$$J = 0.0013$$



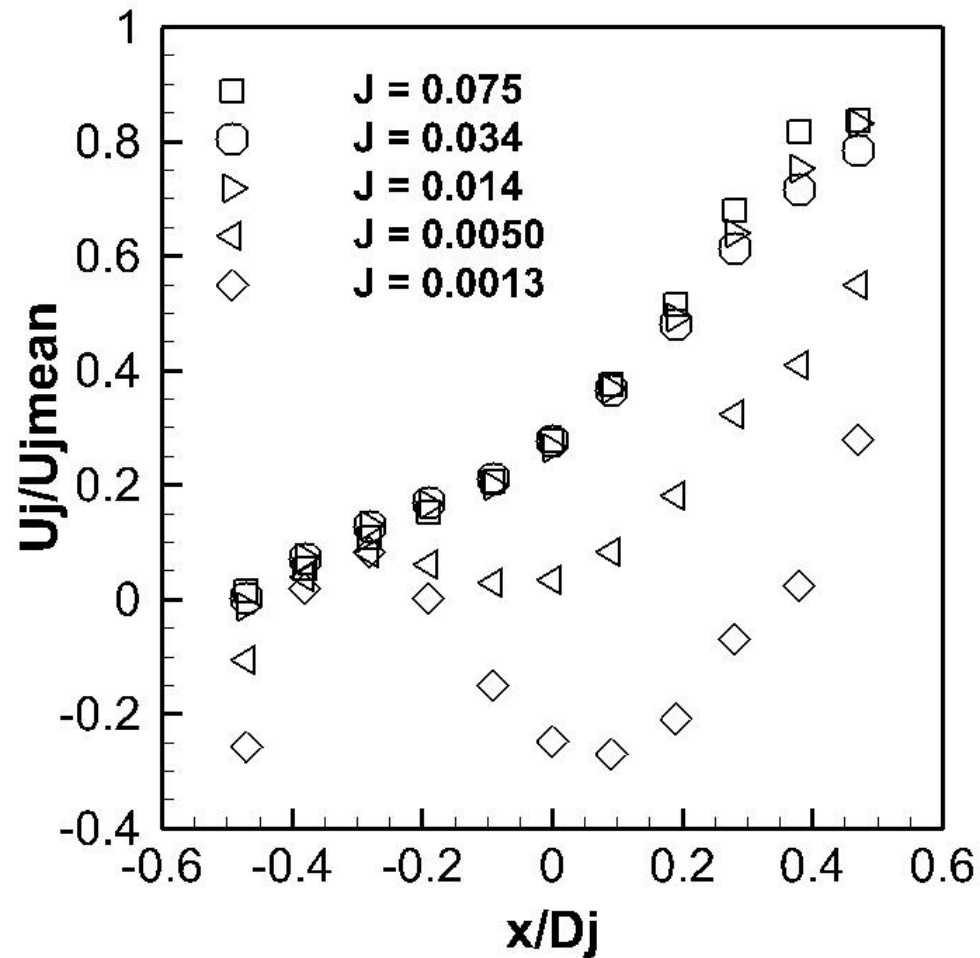


Maximum Jet Penetration



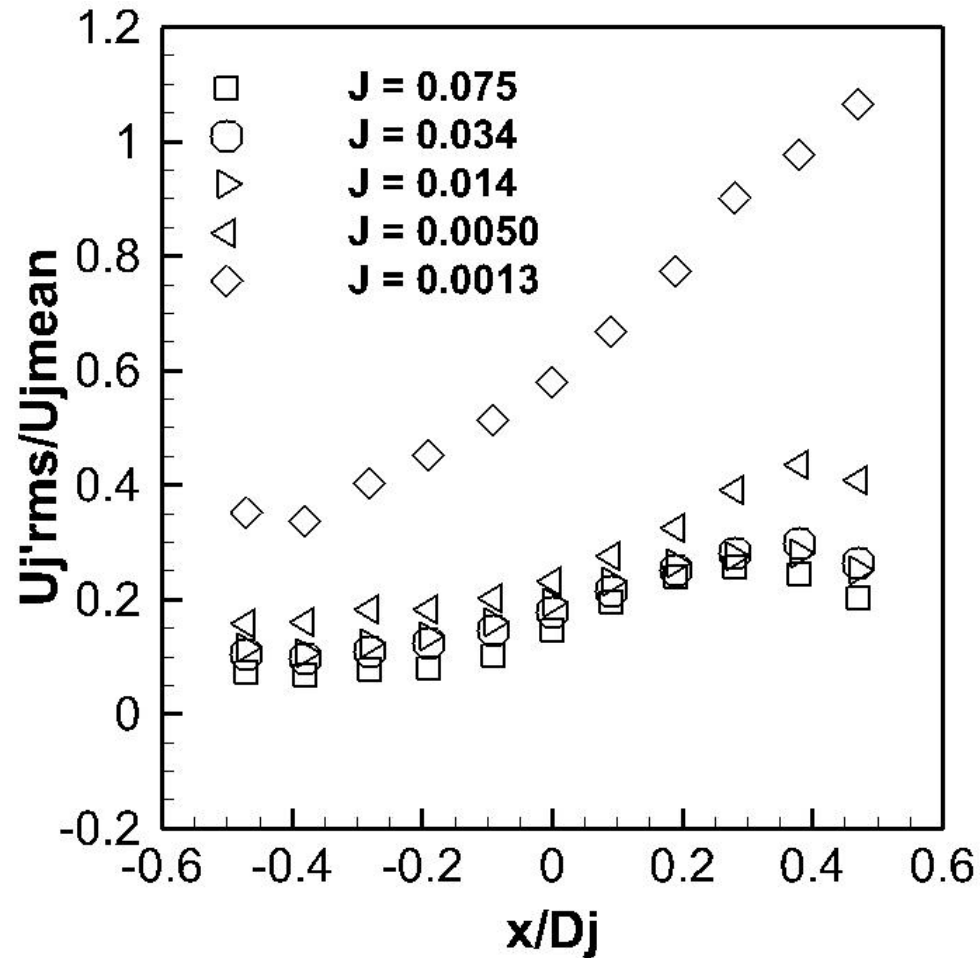


Jet Exit – Velocity Profile



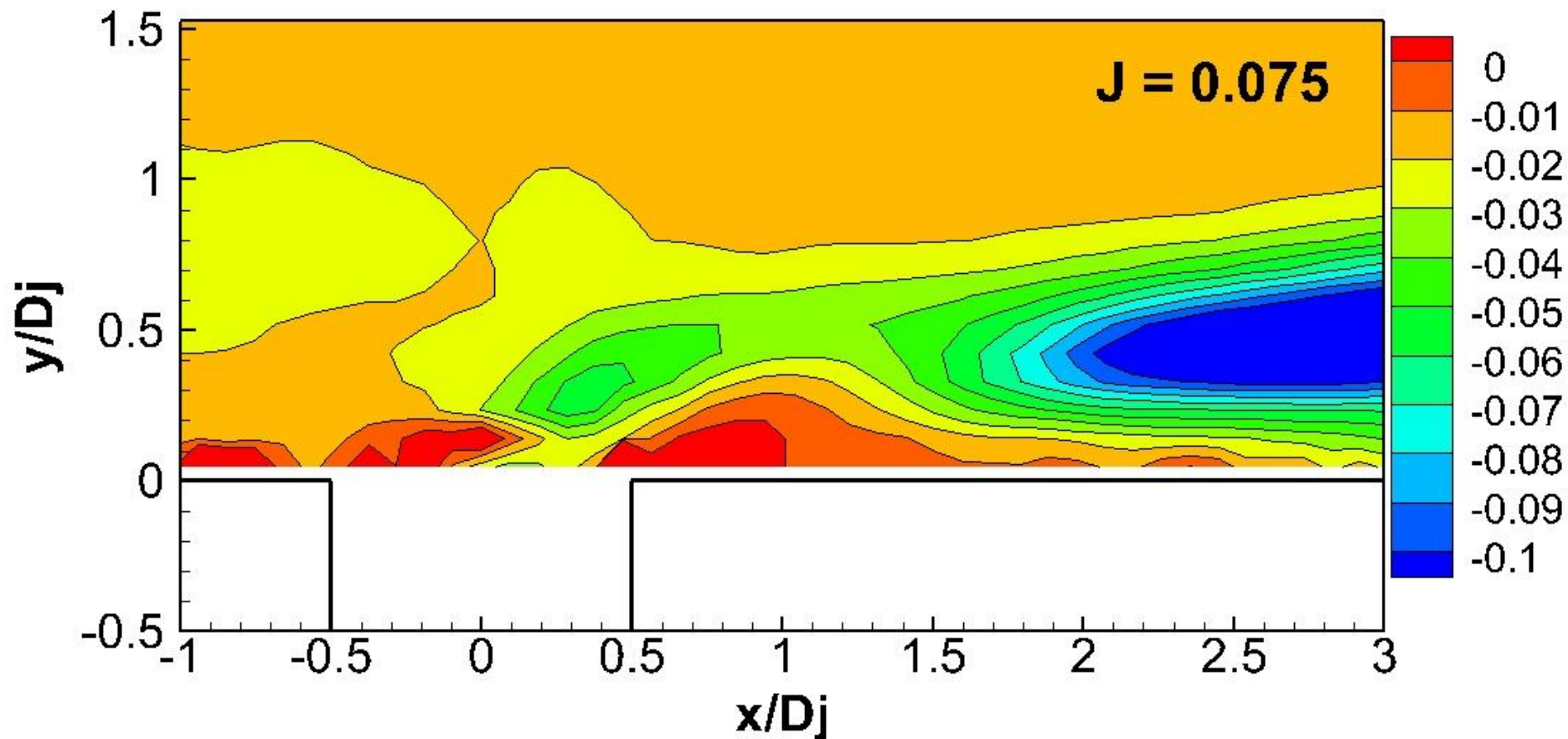


Jet Exit – RMS Profile



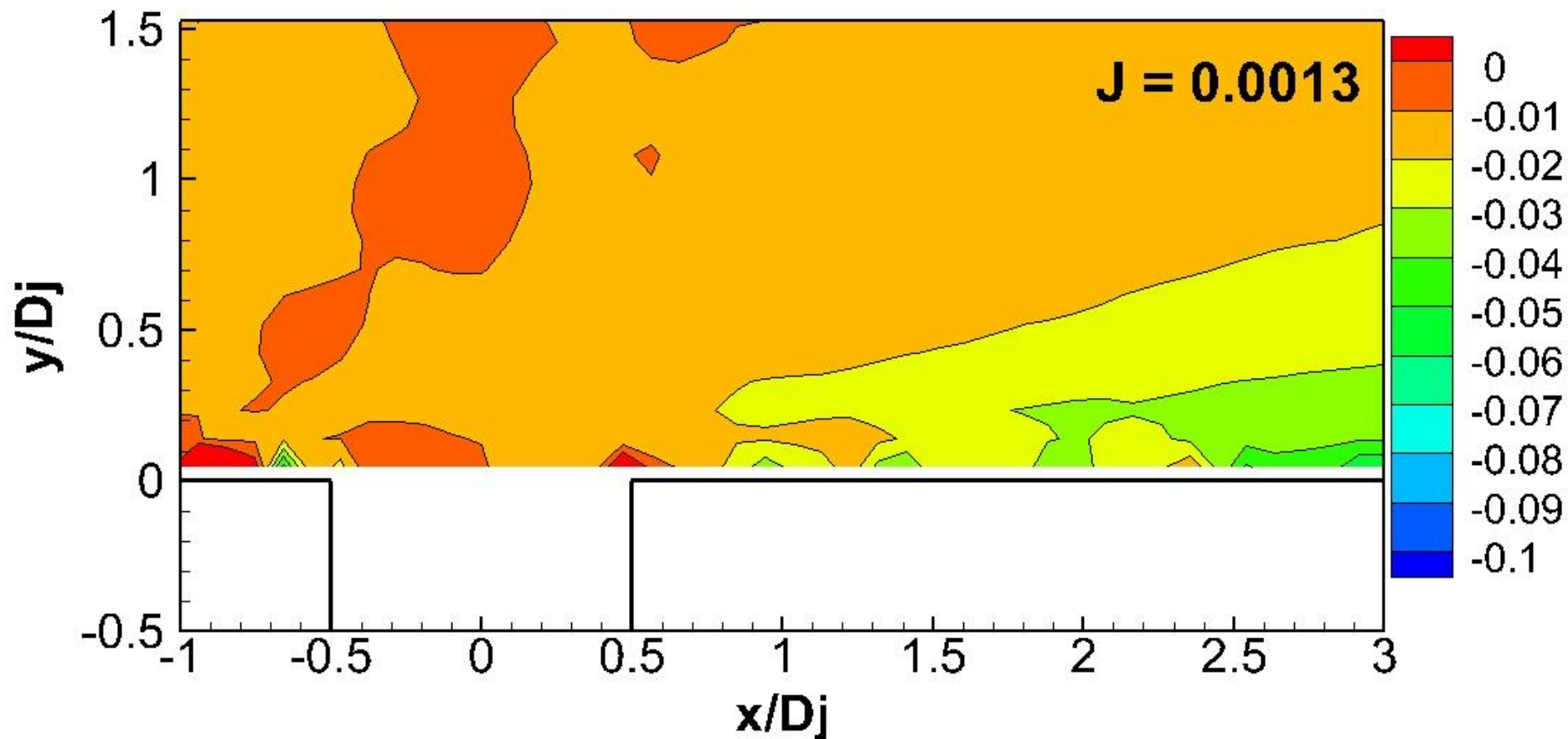


Reynolds Shear Stress, $u'v'$



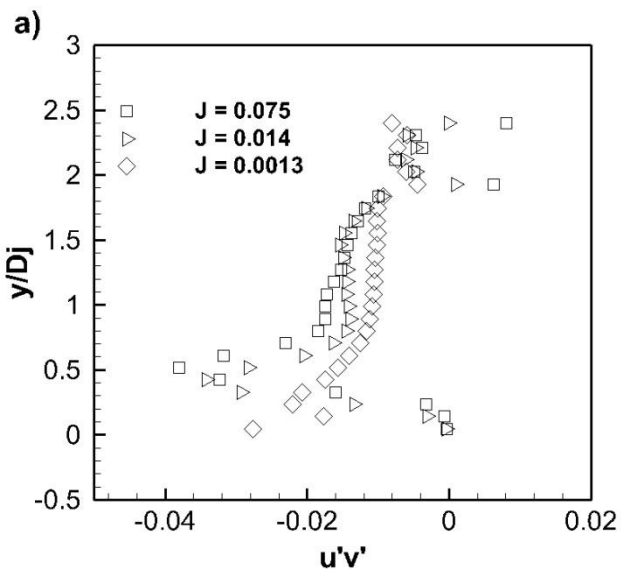


Reynolds Shear Stress, $u'v'$

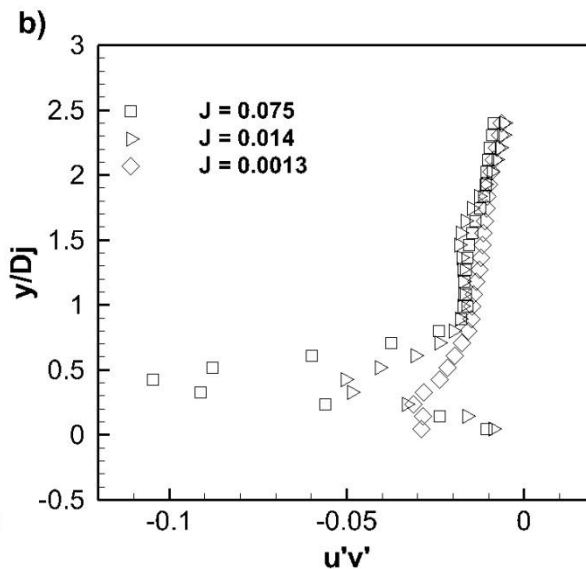




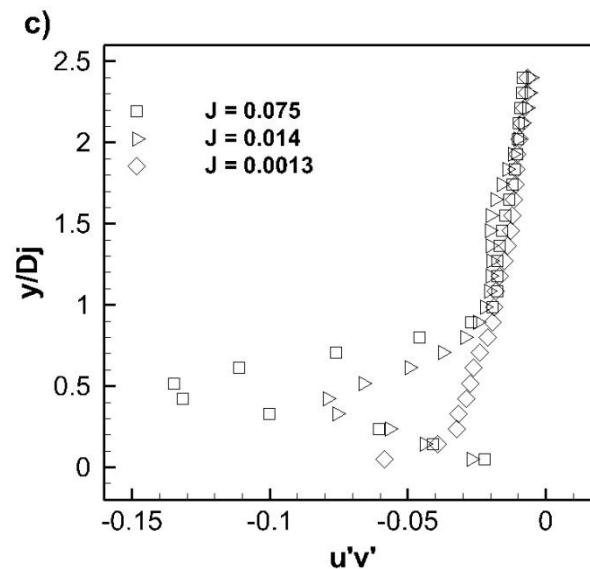
Reynolds Shear Stress, $u'v'$



$$x/D_j = 1$$



$$x/D_j = 2$$



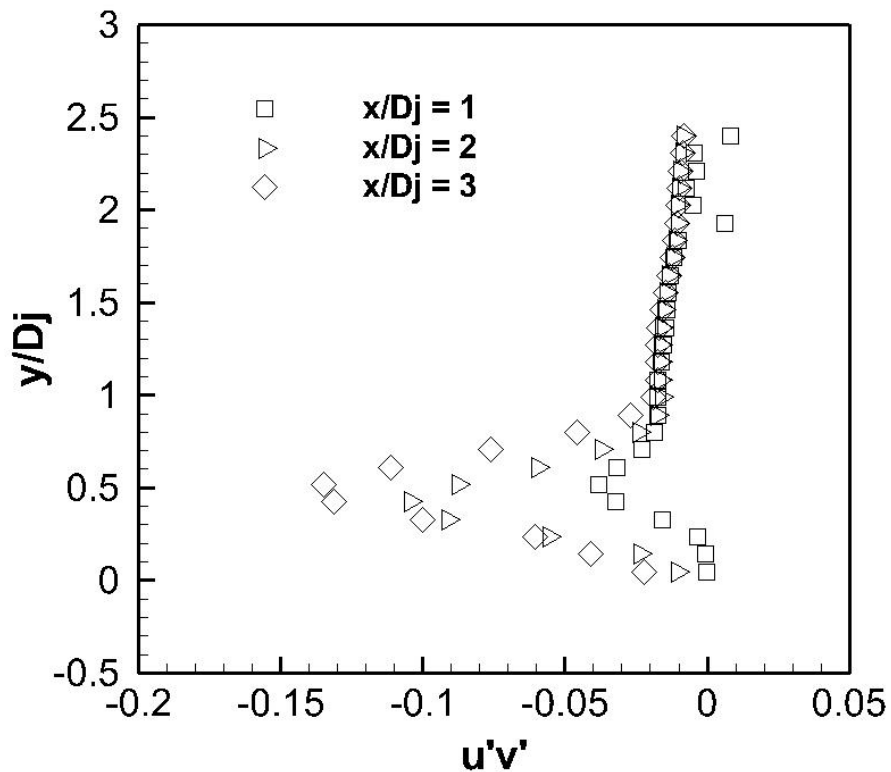
$$x/D_j = 3$$



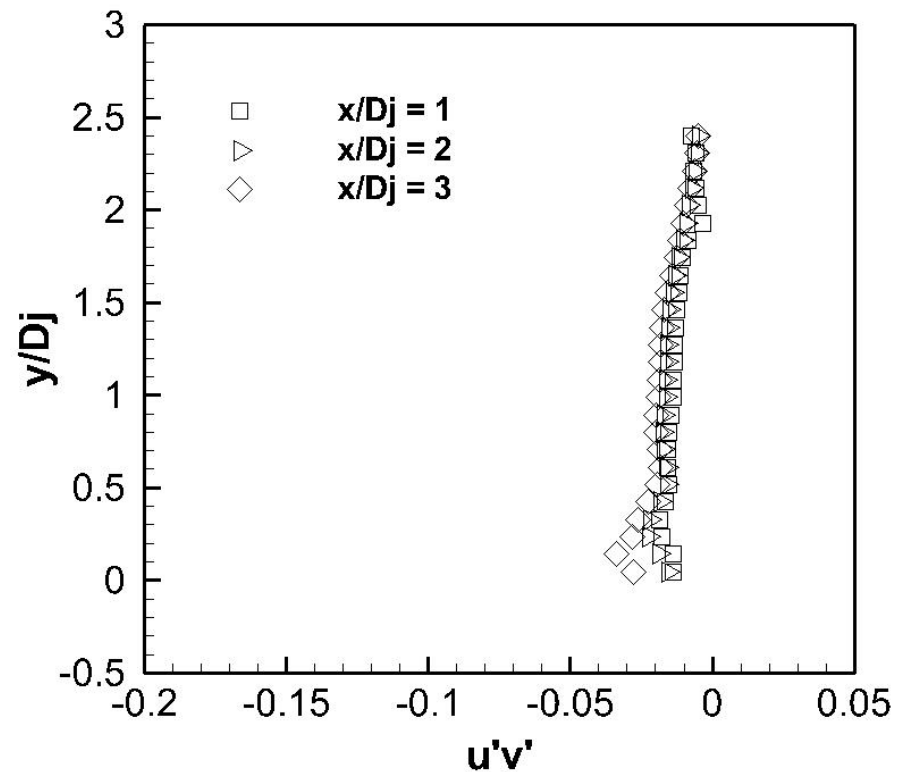
Reynolds Shear Stress, $u'v'$



$J = 0.075$

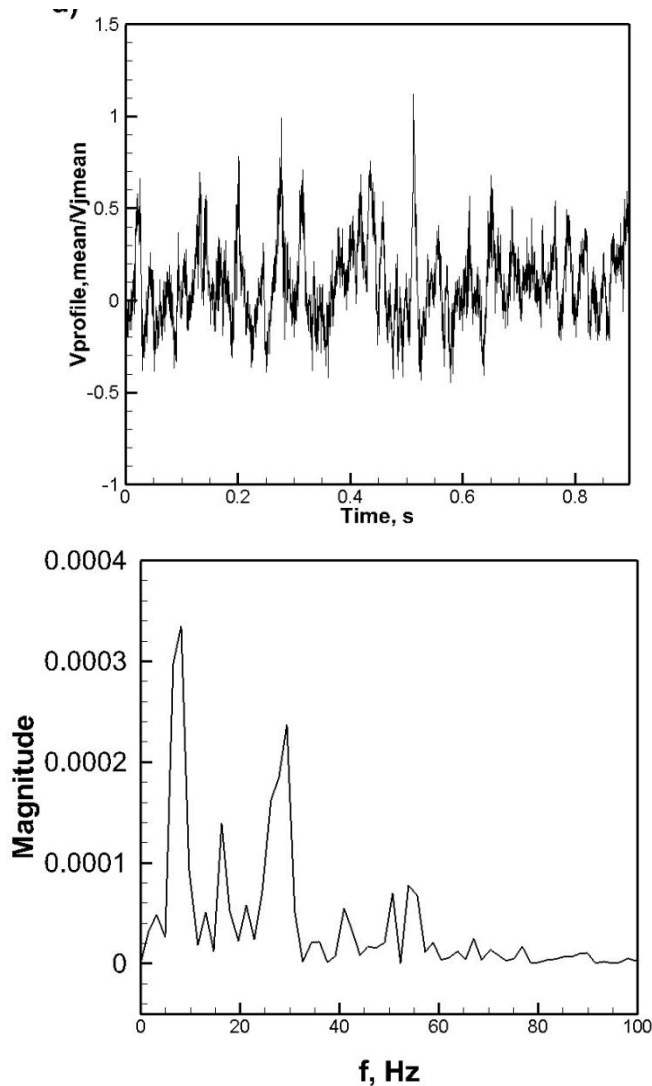


$J = 0.0013$



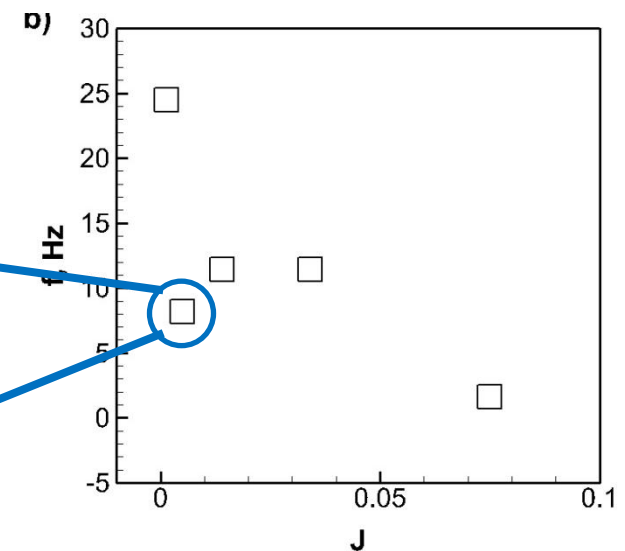


Time Dependent Jet Behavior



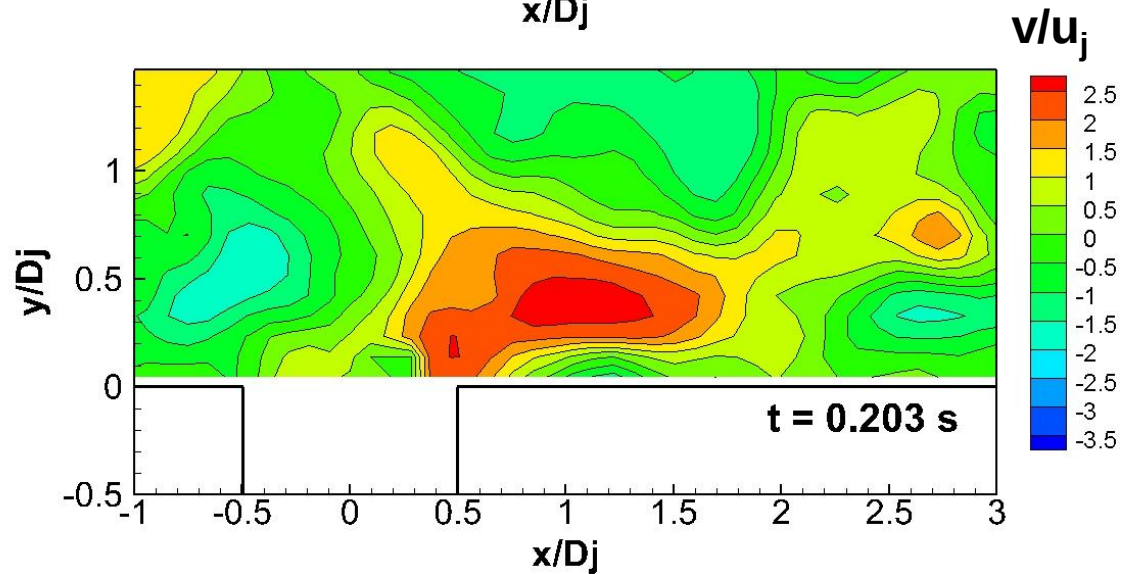
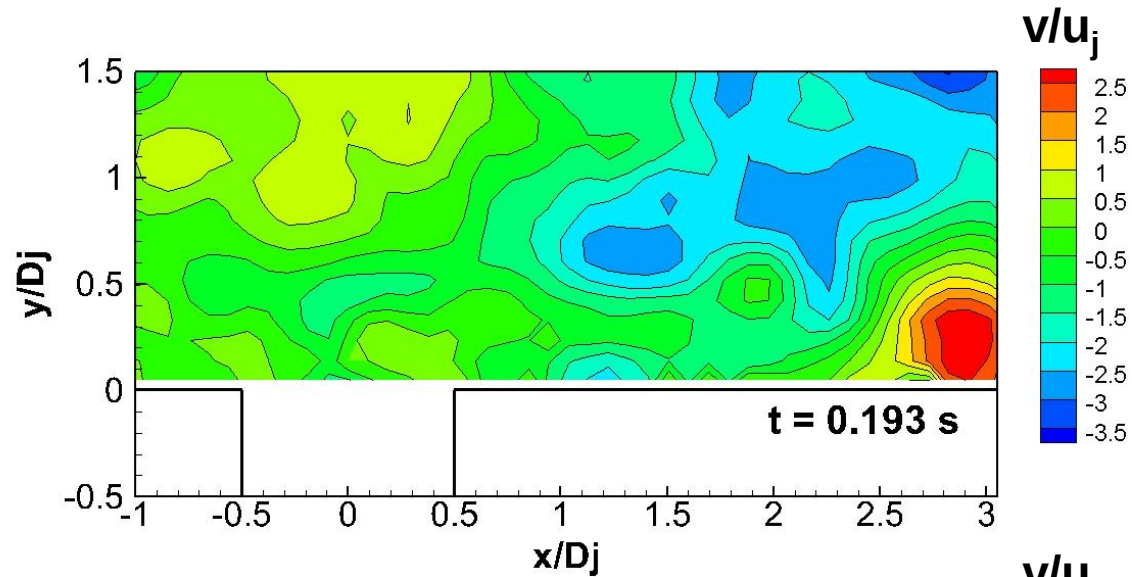
Time domain

Frequency domain





Time Dependent Jet Behavior

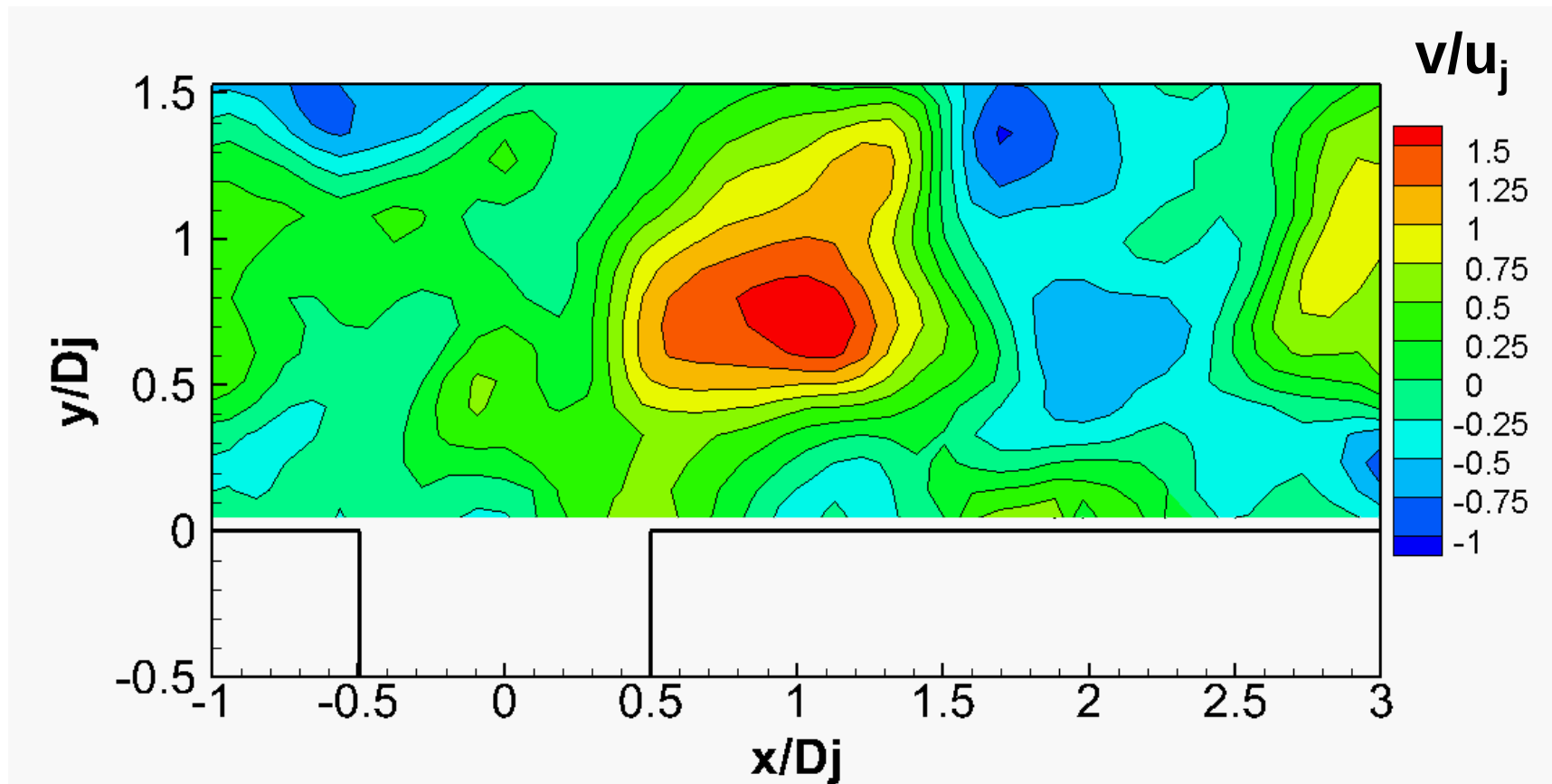




Time Resolved Jet Behavior



$$J = 0.0050$$

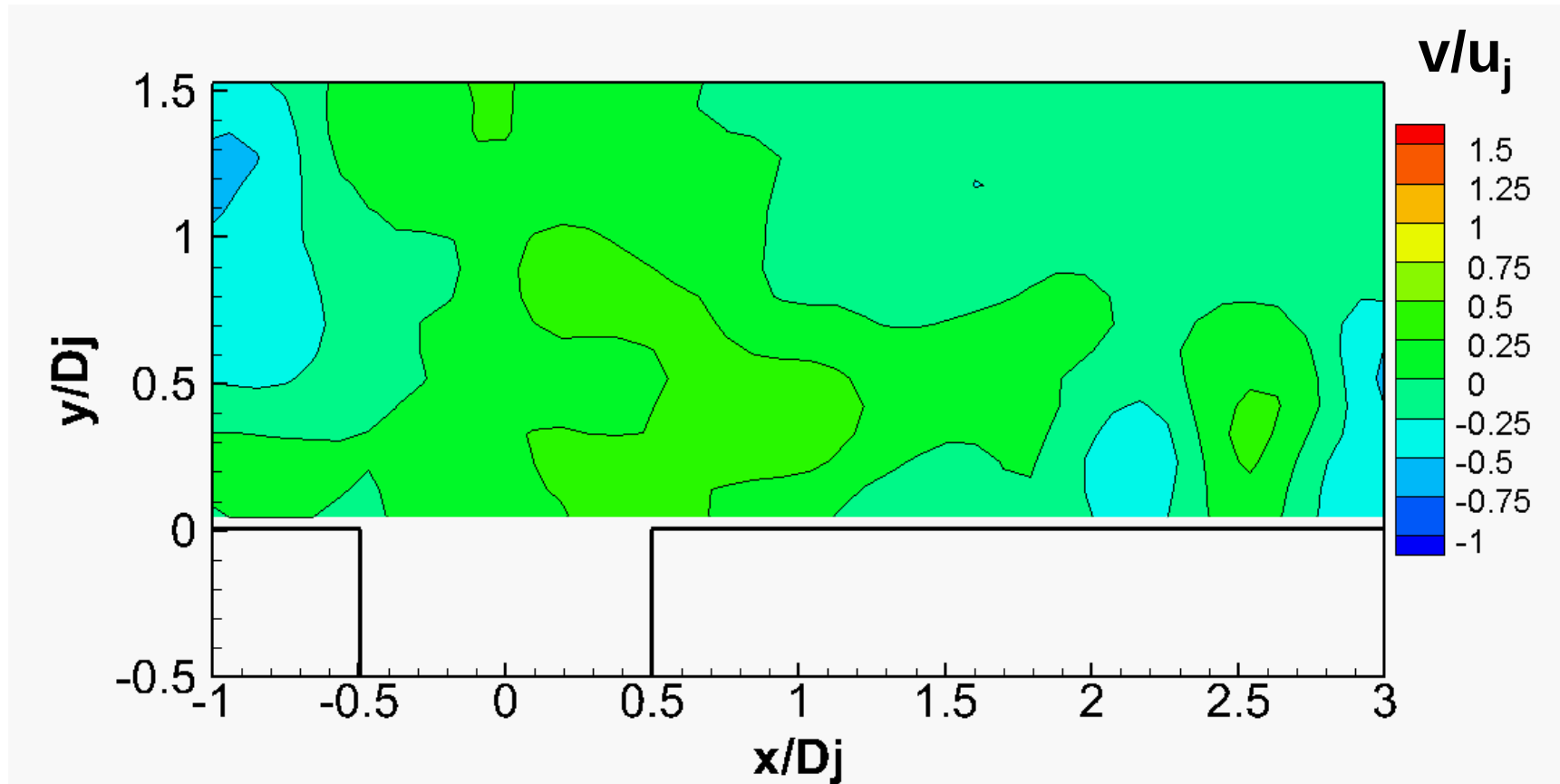




Time Resolved Jet Behavior

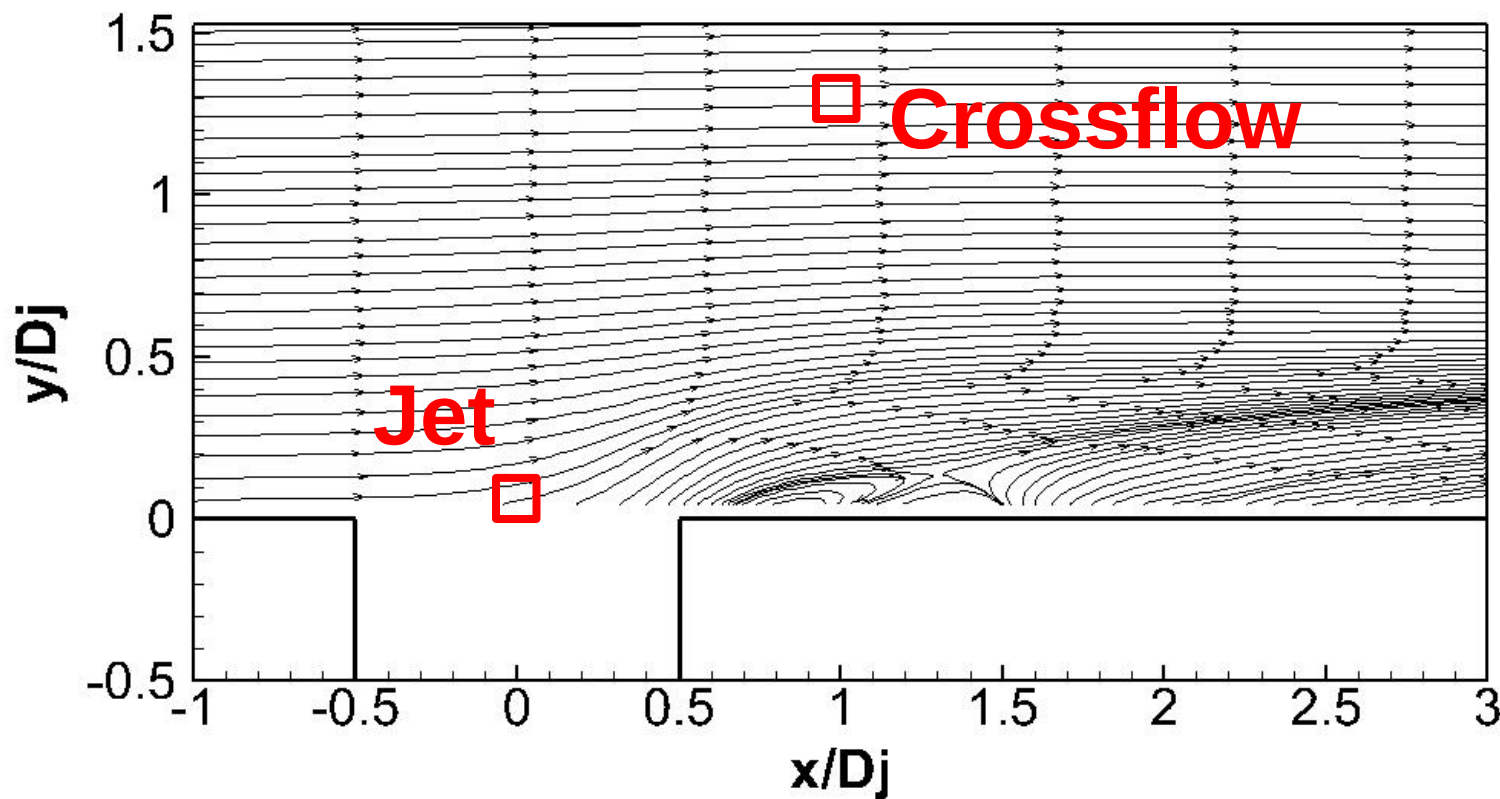


$$J = 0.075$$





PIV Precision Uncertainty





Precision Uncertainty – Jet



<i>J</i>	<i>u'</i> ²	<i>v'</i> ²	<i>u'v'</i>
0.075	0.0591	0.0045	0.0111
0.014	0.0655	0.0008	0.0068
0.0013	0.0844	0.0009	0.0064

$$u_{prec} = 2S_i / N^{1/2}$$

S_i = standard deviation of i^{th} parameter

N = number of samples (3,000)



Conclusion



- **Confirmed jet and crossflow interaction for $M = 0.275$ ($J = 0.075$)**
- **$J = 0.0013$ minimizes crossflow penetration**
- **$J = 0.0013$ is most unstable value of those studied**
- **PIV data provides evidence for highly 3-dimensional jet and crossflow interaction**
- **Reduced Reynolds shear stress values indicate potential improved performance of low momentum jets for use in film cooling applications**
- **Ingestion of crossflow fluid creates pulse-like jet behavior**



Questions?





Backup





Precision Uncertainty – Jet



J	u'	u'^2	$\sqrt{u'^2}$	v'	v'^2	$\sqrt{v'^2}$	$u'v'$
0.075	0.0440	0.0591	0.0222	0.0084	0.0045	0.0057	0.0111
0.034	0.0532	0.0677	0.0235	0.0069	0.0019	0.0041	0.0095
0.014	0.0520	0.0655	0.0238	0.0048	0.0008	0.0028	0.0068
0.0050	0.0490	0.0714	0.0255	0.0033	0.0005	0.0021	0.0045
0.0013	0.0488	0.0844	0.0279	0.0042	0.0009	0.0027	0.0064



Precision Uncertainty - Crossflow



J	u'	u'^2	$\sqrt{u'^2}$	v'	v'^2	$\sqrt{v'^2}$	$u'v'$
0.075	0.0186	0.0577	0.0123	0.0103	0.0051	0.0067	0.0053
0.034	0.0224	0.0961	0.0170	0.0098	0.0045	0.0063	0.0043
0.014	0.0195	0.0542	0.0127	0.0090	0.0036	0.0057	0.0044
0.0050	0.0218	0.0975	0.0167	0.0093	0.0042	0.0060	0.0043
0.0013	0.0170	0.0415	0.0109	0.0090	0.0038	0.0057	0.0051



Experimental Conditions



- **Particle Image Velocimetry (PIV) Parameters**
 - 527 nm light source
 - 100 ns pulses
 - 0.5 mJ/pulse
 - Image-pair time separation = 120 μ s
 - Image-pair capture rate = 3348 Hz
 - Particle diameter = 1 μ m
 - 20 particle per 32 x 32 pixel interrogation region
- **Crossflow**
 - $Re_o = 14,000$
 - $u_o = 2.71$ m/s
- **Jet**
 - $62 < Re_j < 472$
 - $u_j = 0.731$ m/s