An Experimental and Numerical Investigation of Scalar and Momentum Transport in Mixing Layers*

Ning Li*†*, Elias Balaras and James Wallace

Department of Mechanical Engineering
University of Maryland, U.S.A.

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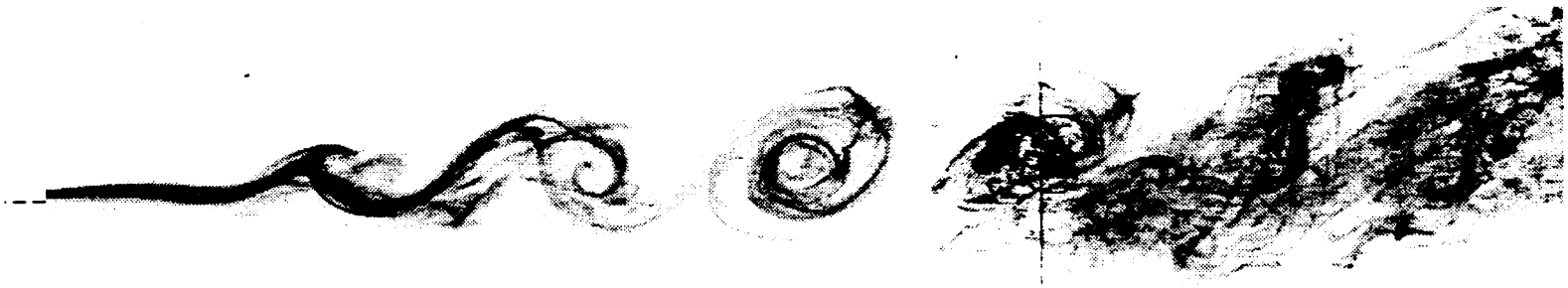
† Imperial College of Science and Technology

Overview of Presentation

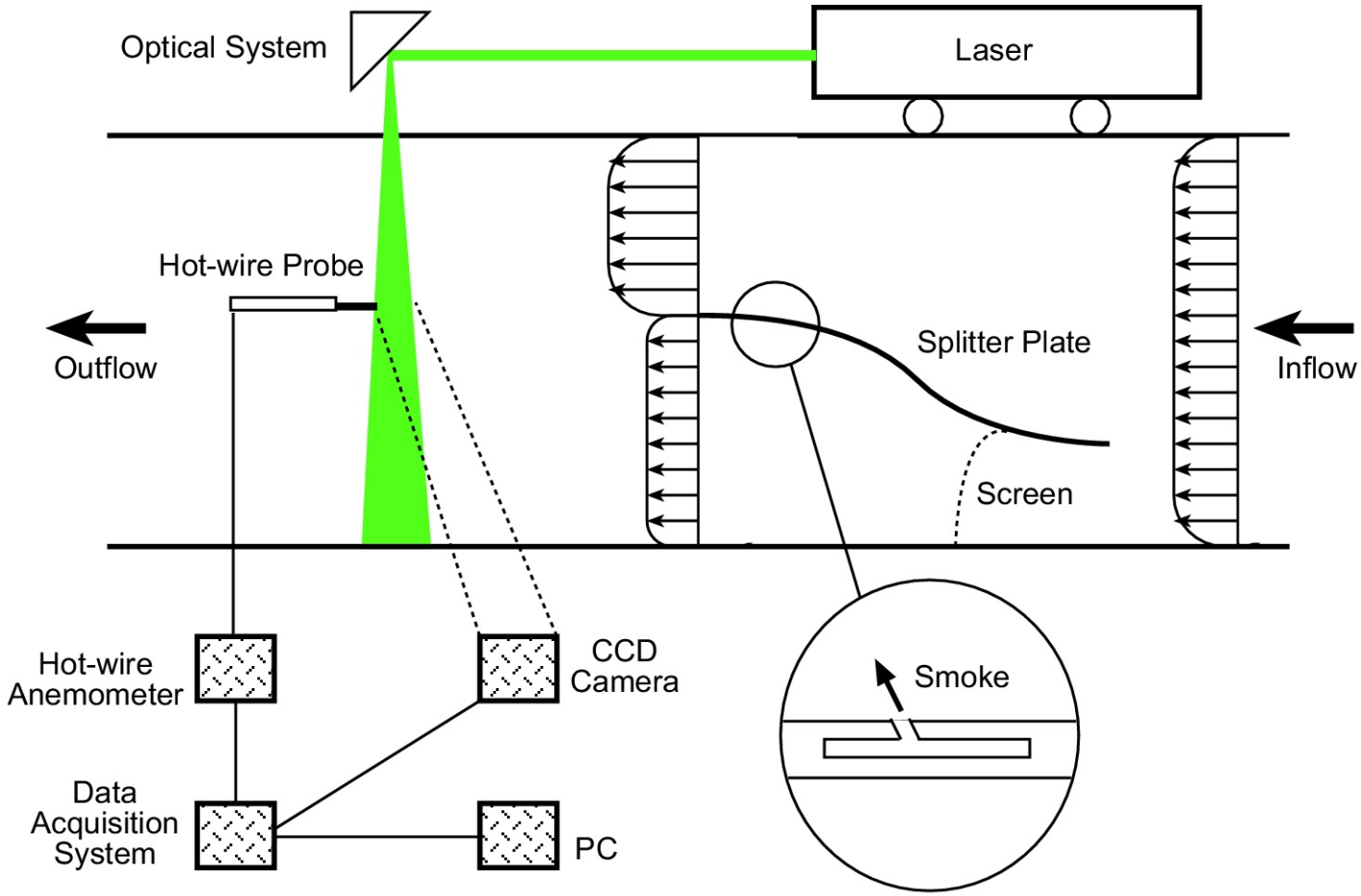
- ***Description of Experiment***
  - Facility
  - 12-sensor hot-wire probe for velocity and vorticity measurements
  - Optical arrangement for Mie-scattering scalar concentration measurements
- ***Description of LES***
  - Computational Scheme
  - Initial Conditions
  - Grid Refinement
- ***Results***
  - Statistics
  - Flow Structure
  - Transport Mechanisms
- ***Summary***

Photo of two-stream mixing layer in transition

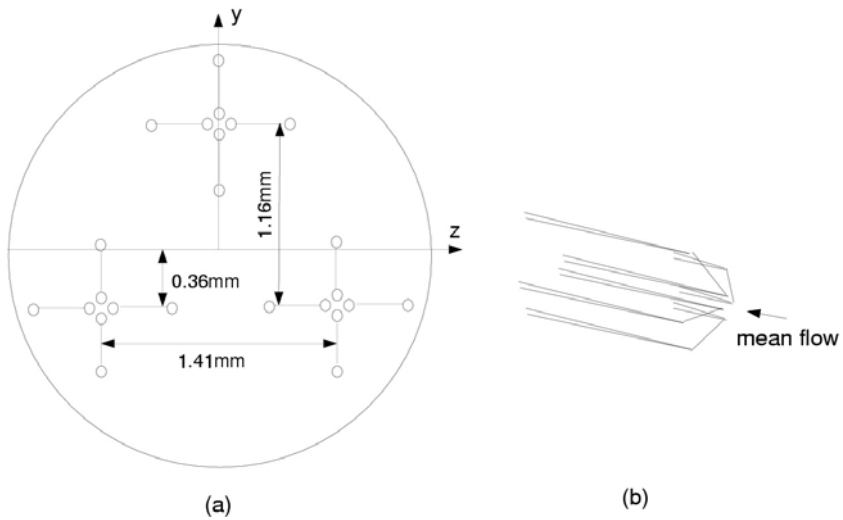


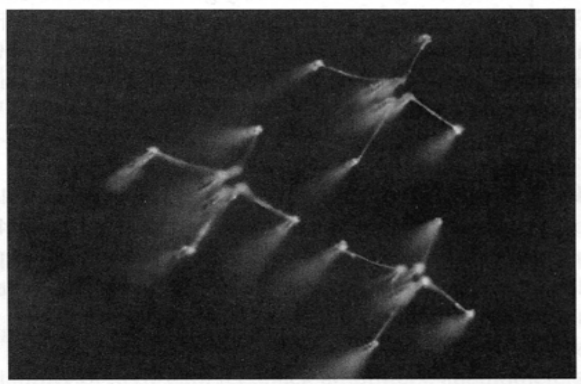
Turbulent “roller” vortices are seen downstream. $R_\theta \sim 1600$ at measurment location in self-similar region.

Experimental Setup

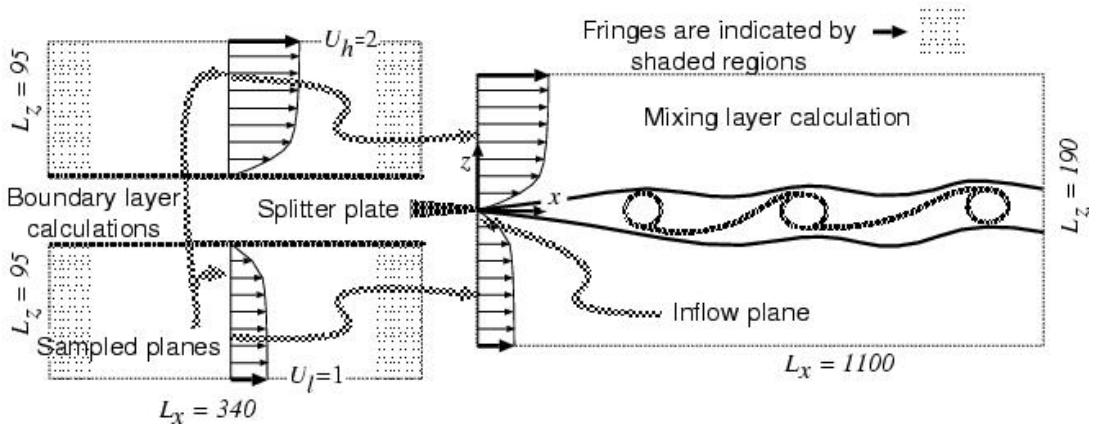


Twelve-sensor probe for velocity vector & velocity gradient measurements



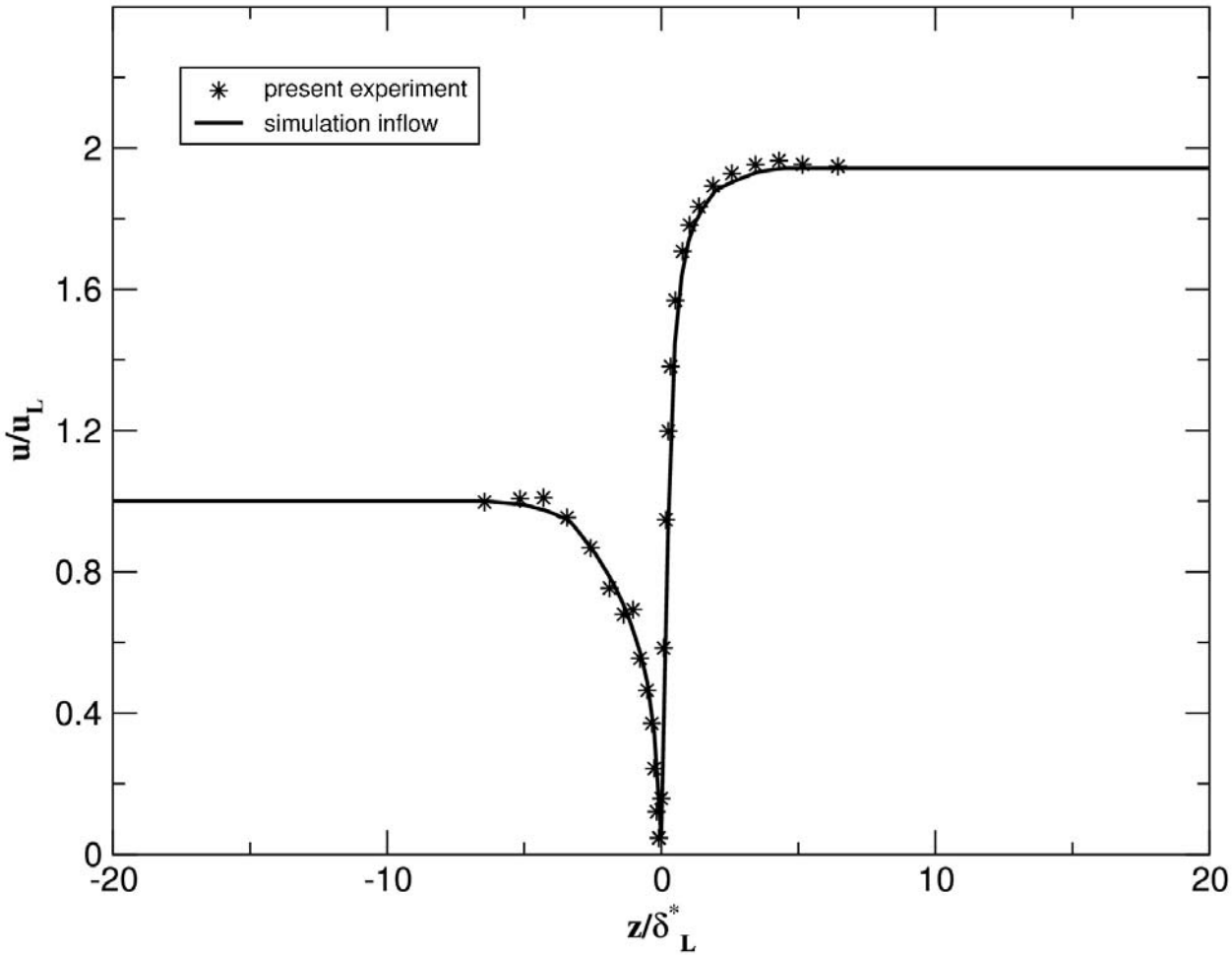


Large-eddy simulation



- Fractional step method with central 2nd order finite differences
- Staggered grid with 380×96×96 points (3.5M)
- Boundary conditions:
  - Inflow: parallel B.L. computations
  - Outflow: convective b.c.
  - Freestream: radiative b.c.
- Scalar transport: simulated tracking massless particles (10M)

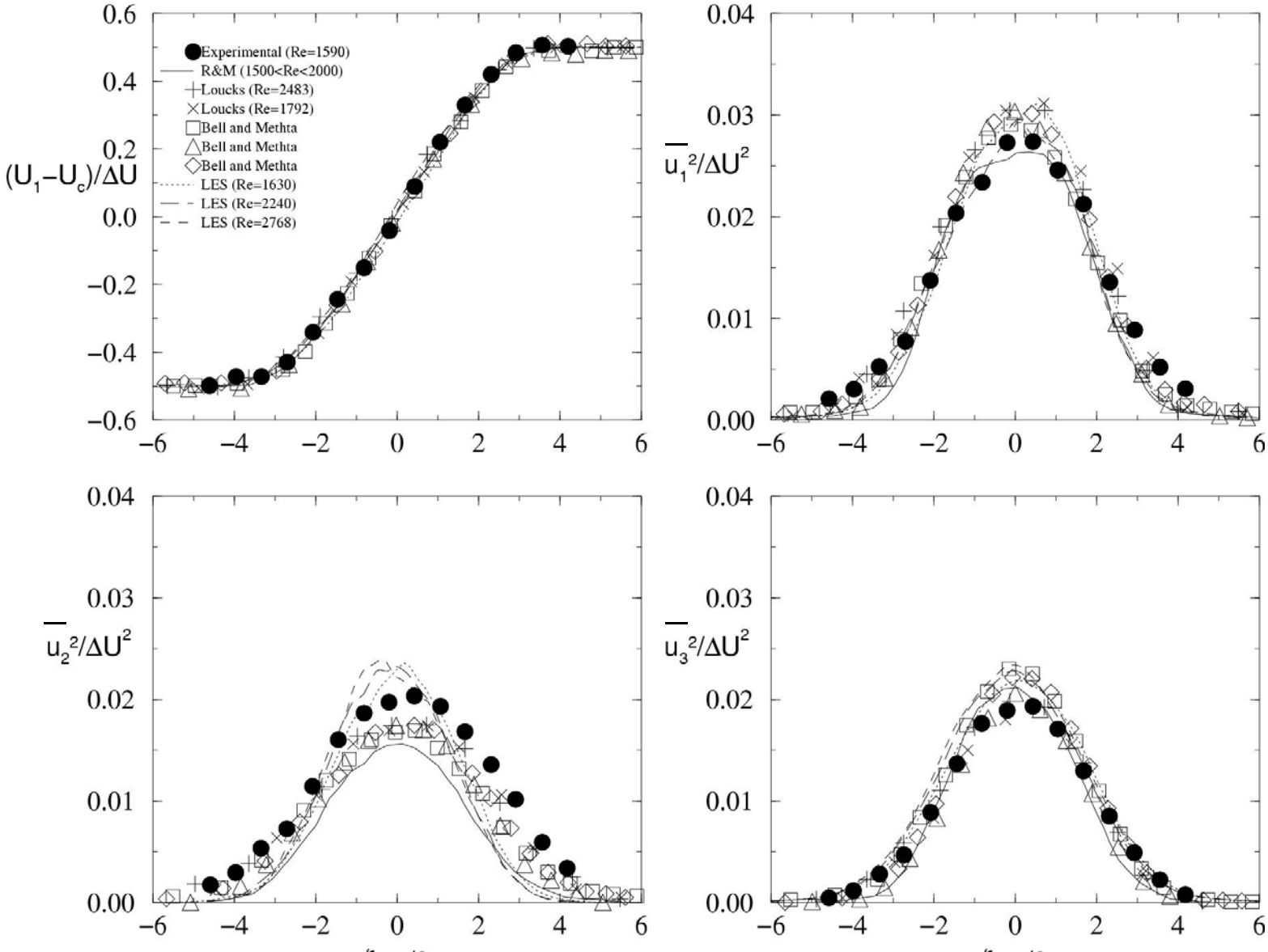
Matching Experimental & LES Inflow Conditions



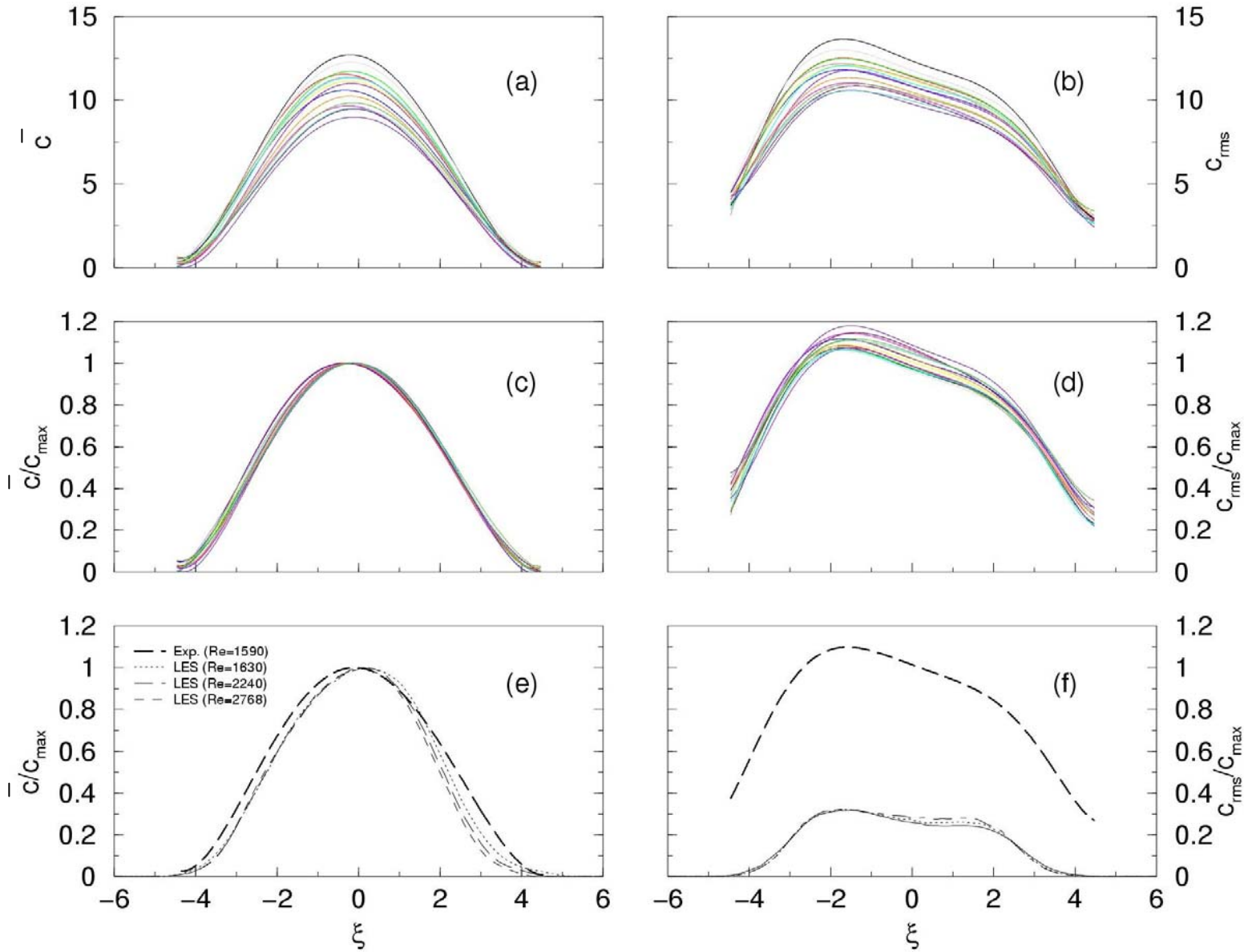
Comparison Properties

	Re_θ	$d\theta/dx$
Present Experimental Study	1,590	0.013
Present Numerical Study (LES)	1,500-3,900	0.013
Loucks [35]	2,483 1,792 432	0.016
Bell & Metha [7]	2,800 1,900 1,570	0.010
Rogers & Moser (DNS) [50]	1,500-2,000	0.014

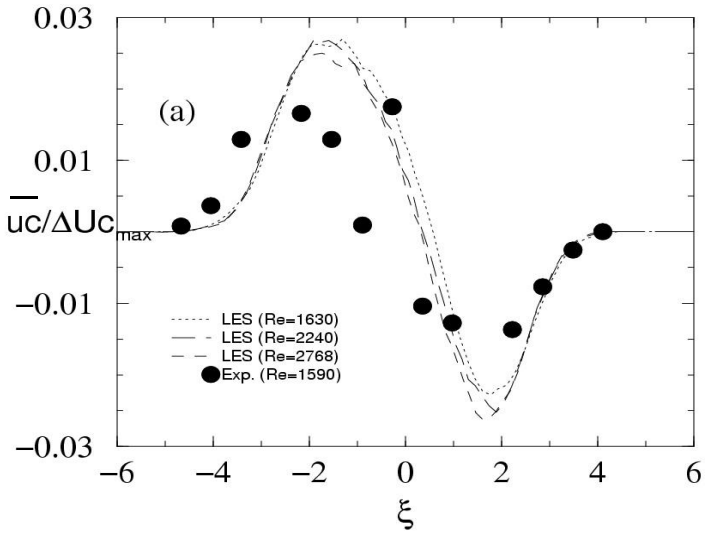
Velocity Statistics

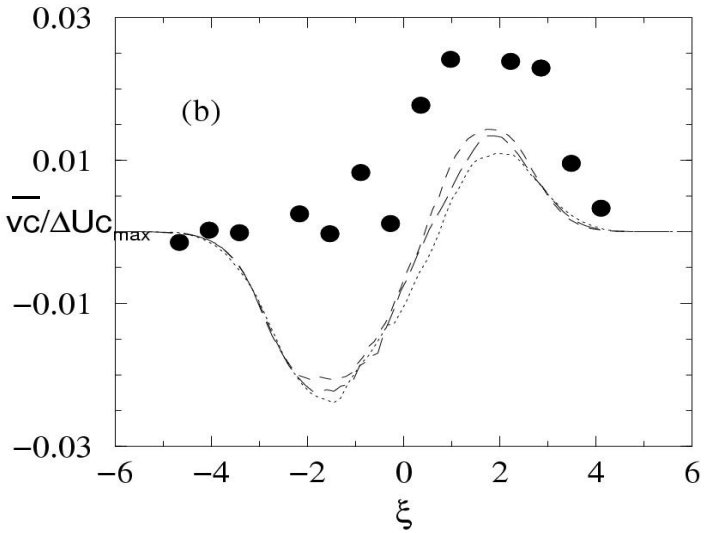


Concentration Statistics



Scalar & Momentum Fluxes





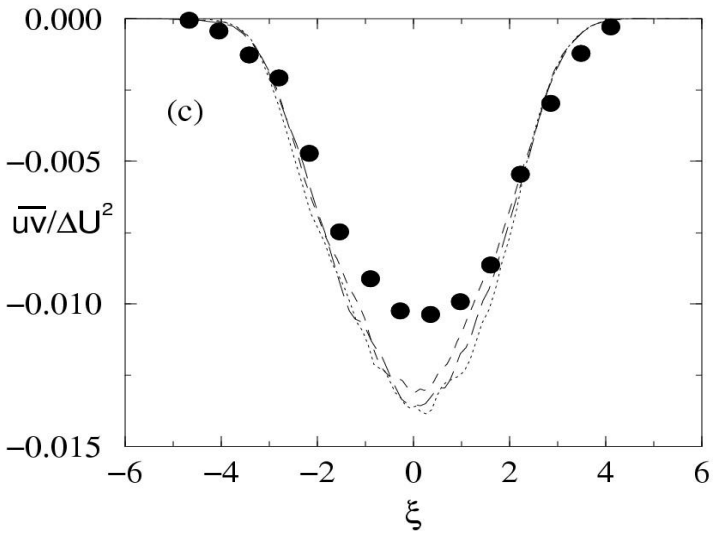
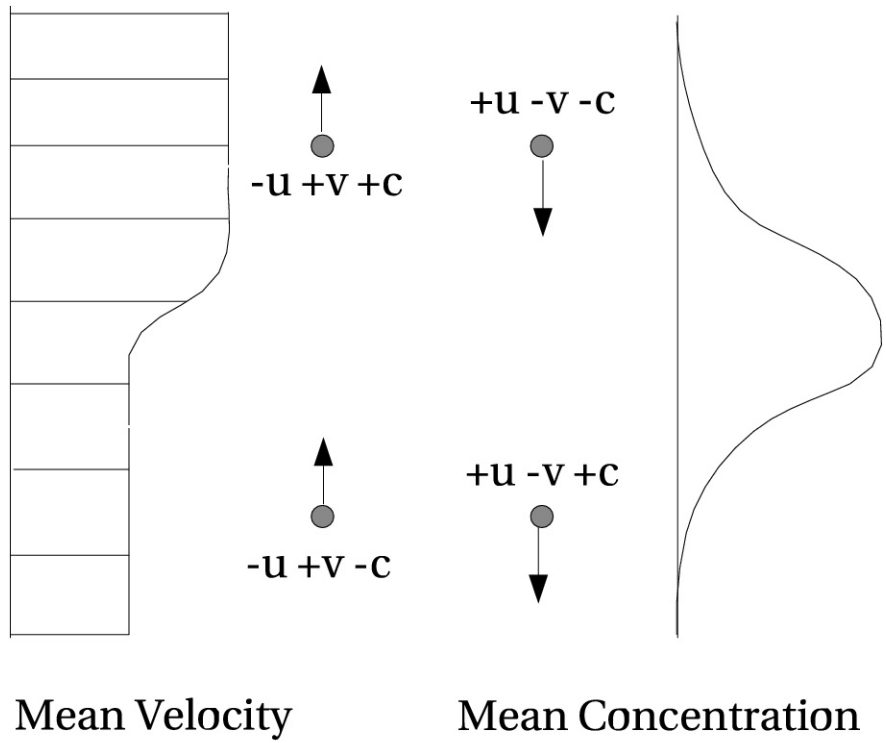
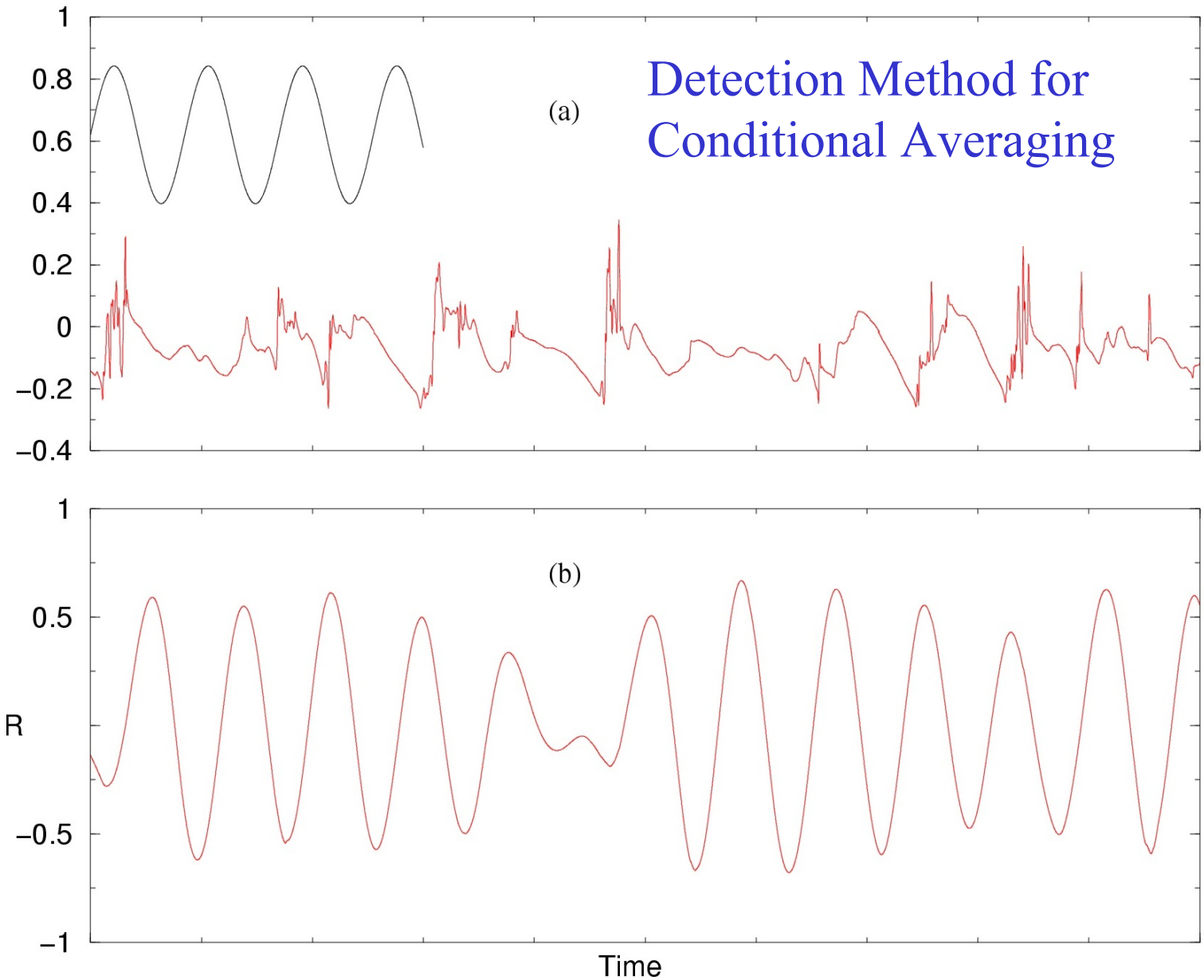


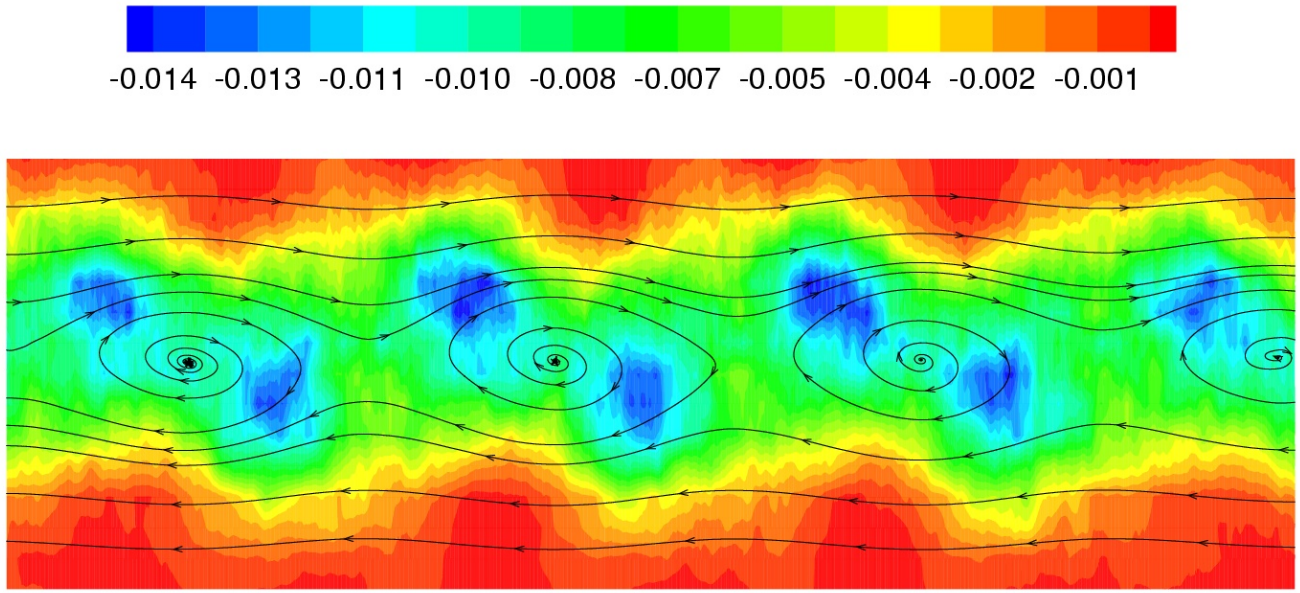
Illustration of Mean Gradient Transport



Detection Method for Conditional Averaging



Conditionally Averaged “Roller” Vortices (streamlines) & Reynolds Shear Stress (color contours)



Conditionally Averaged scalar fluxes

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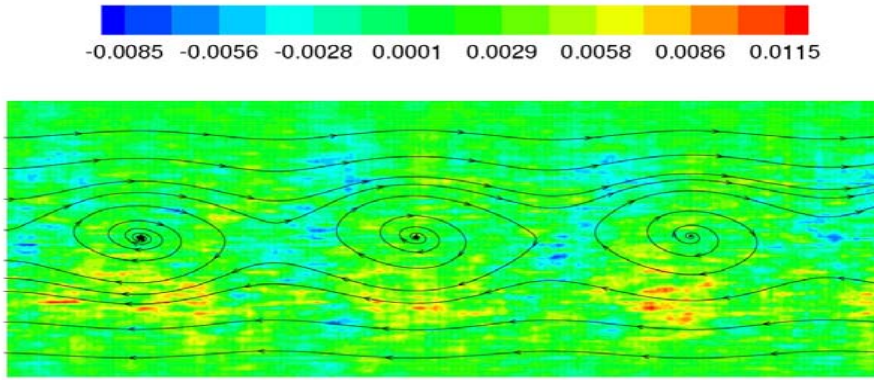

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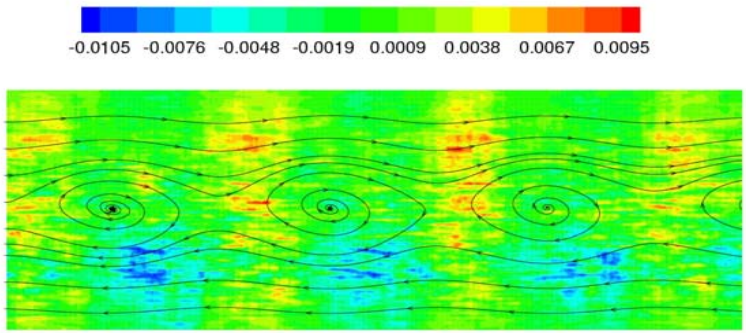

Spanwise Averaged "Roller" Vortices & Scalar Fluxes from LES

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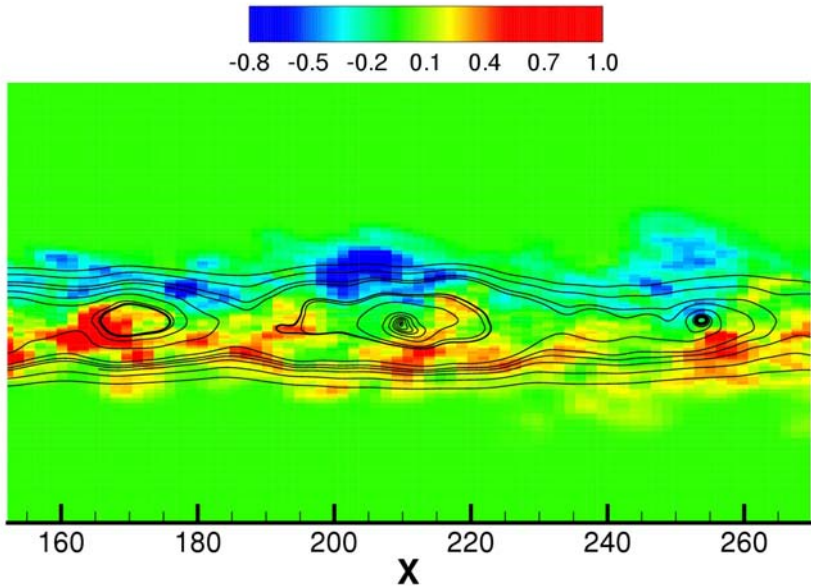

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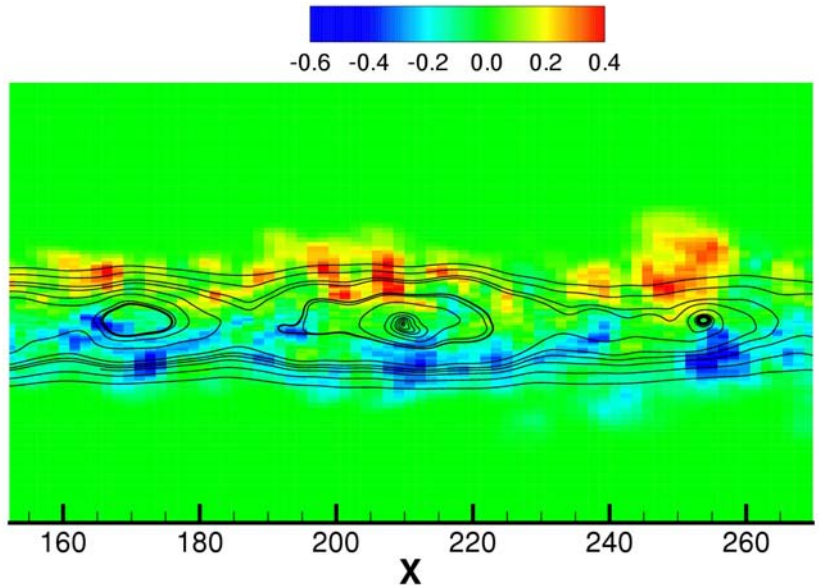
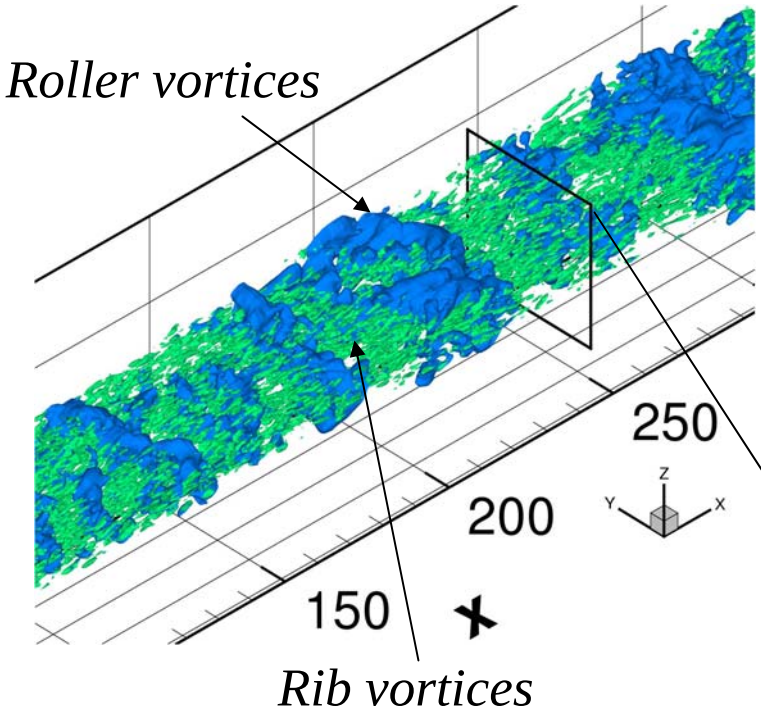
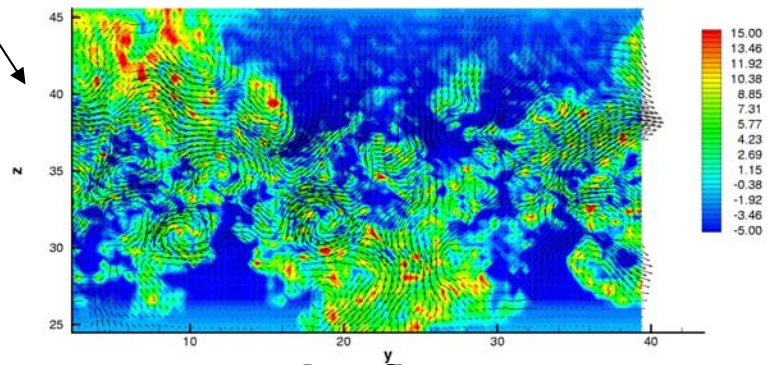
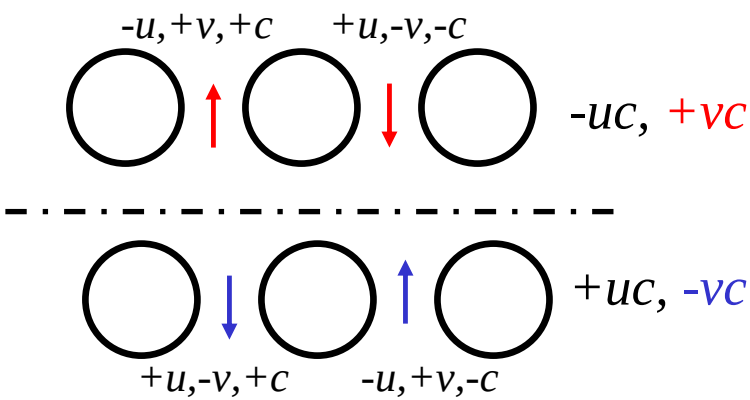


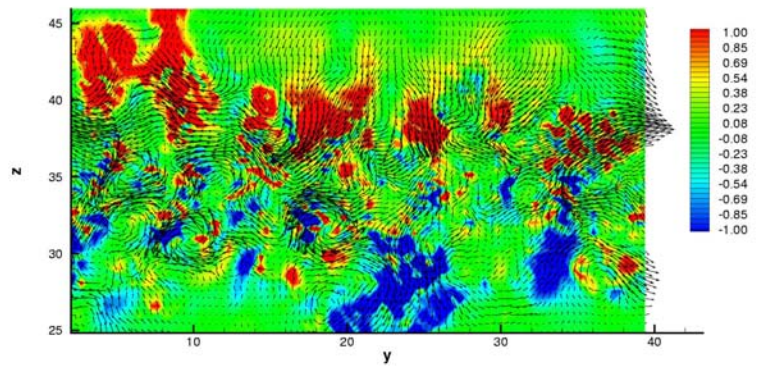


Scalar fluctuations, c





Scalar flux, vc



Summary

- A Multi-sensor hot-wire probe and optical system was used to measure the scalar and momentum flux in a two-stream mixing layer.
- LES was used to study the scalar and momentum transport processes in this flow
- Experimental and Computational velocity and vorticity field statistics are in reasonable agreement with each other and sources from the literature.
- Conditional averaging revealed the spatial locations of the highest scalar and momentum flux intensities occur in the “braid” on the periphery of the “roller” vortices.
- An instantaneous realization of the 3-D LES field revealed that the scalar transport is primarily of the mean gradient type and is closely associated with the pumping action between the “rib” vortices in the “braid” between the rollers.