Presented at the COMSOL Conference 2010 Boston

Influence of Inlet Fluctuations on the Development of the Turbulent Two-Stream Mixing Layer

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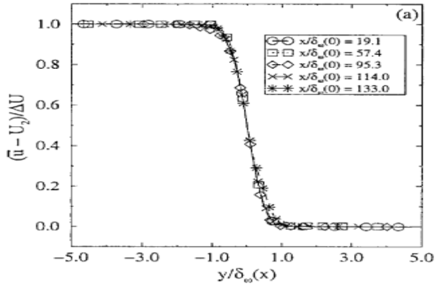
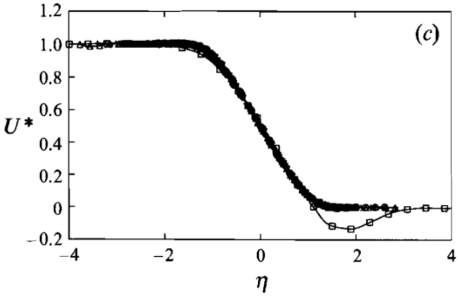
COMSOL 2010 Conference | Boston, MA | October 7, 2010

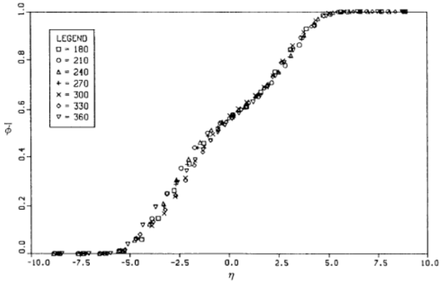
Introduction and motivation



Stanley, Scott and Sarkar, Sutanu. *"Simulations of Spatially Developing Two-Dimensional Shear Layers and Jets." Theoretical and Computational Fluid Dynamics. vol. 9, pp. 121-147. (1997)*



Plesniak, Michael W.; Mehta, Rabindra D.; Johnston, James P.
Curved two-stream turbulent mixing layers: Three-dimensional structure and streamwise evolution, Journal of Fluid Mechanics, 270, pp. 1-50. (1994) ***Experimental***

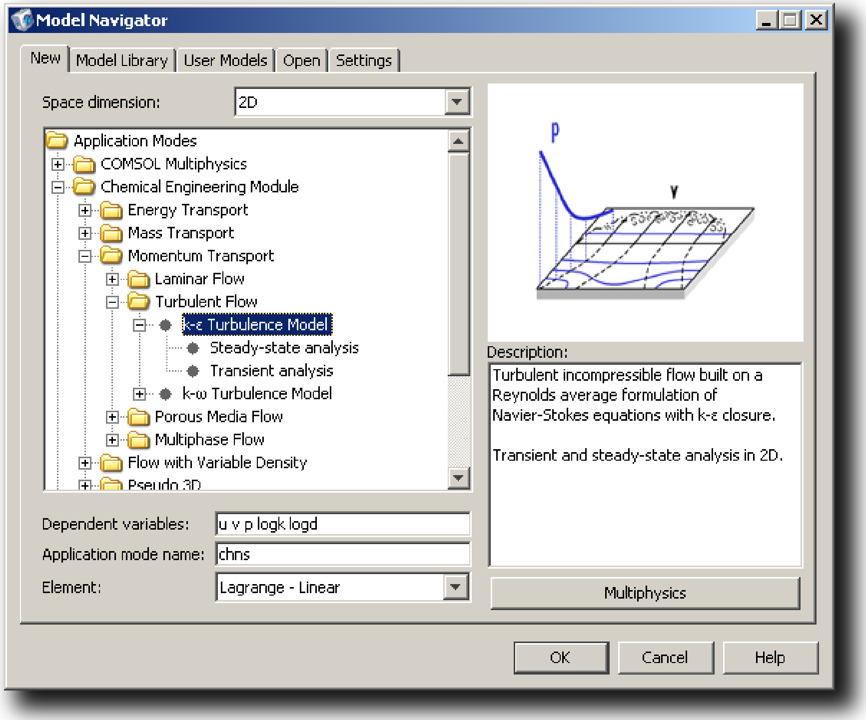


Sandham, N.D., and Reynolds, W. C. *"Some inlet plane effects on the numerically simulated spatially two dimensional mixing layer." in Symposium on Turbulent Shear Flows, 6th, Toulouse, France, Sept. 7-9, 1987, Proceedings (A88-38951 15-34). University Park, PA, Pennsylvania State University. pp. 22-4-1 to 22-4-6. (1987)*

Problem description

Investigate new methods to predict the overall flow-field quantities of spatially evolving free shear flows.

- *k-ε* model from COMSOL 3.5a
- Fluctuating conditions at the inlet



Space dimension: 2D

Dependent variables: u v p logk logd

Application mode name: chns

Element: Lagrange - Linear

Description:

Turbulent incompressible flow built on a Reynolds average formulation of Navier-Stokes equations with k-ε closure.

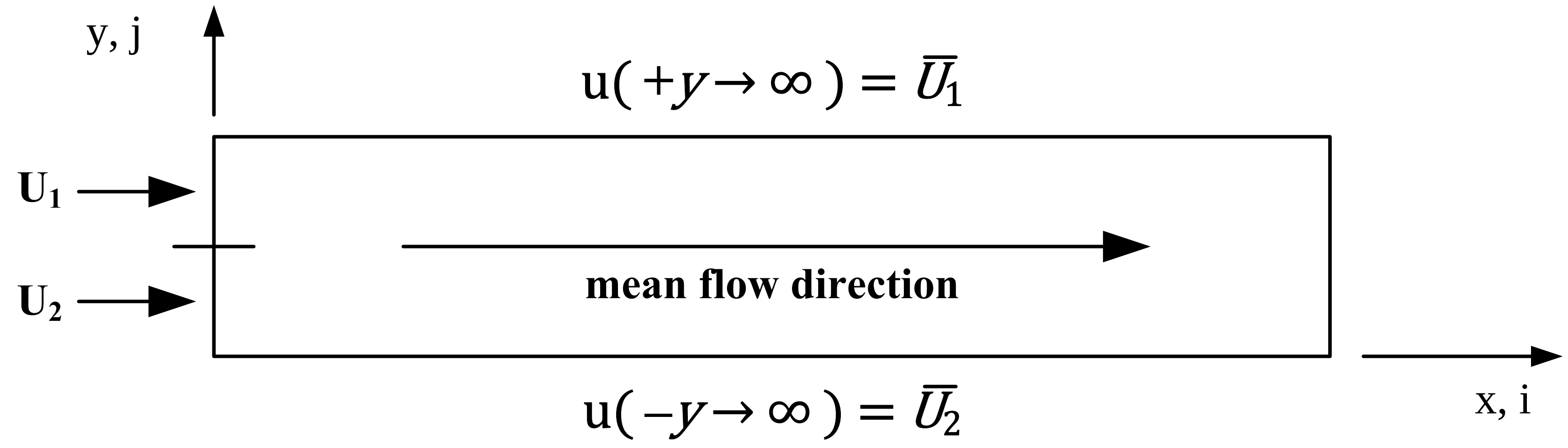
Transient and steady-state analysis in 2D.

Computational procedure overview

1. Initialize a steady-state solution (3 m x 10 m)
   - Calculate an estimate for shear layer thickness, $\delta_s(0)$
   - Reconfigure domain to $\mathbf{40}\delta_s(0) \times \mathbf{143}\delta_s(0)$
2. Calculate a steady-state solution for the reconfigured domain
3. Using domain velocity from step 2 as IC, calculate transient response to a fluctuating inlet velocity

$$\delta_s(x) = \frac{\bar{U}_1 - \bar{U}_2}{(\partial\bar{u}/\partial y)_{max,y=0}}$$

Domain & Boundaries



y, j

$u(+y \to \infty) = \bar{U}_1$

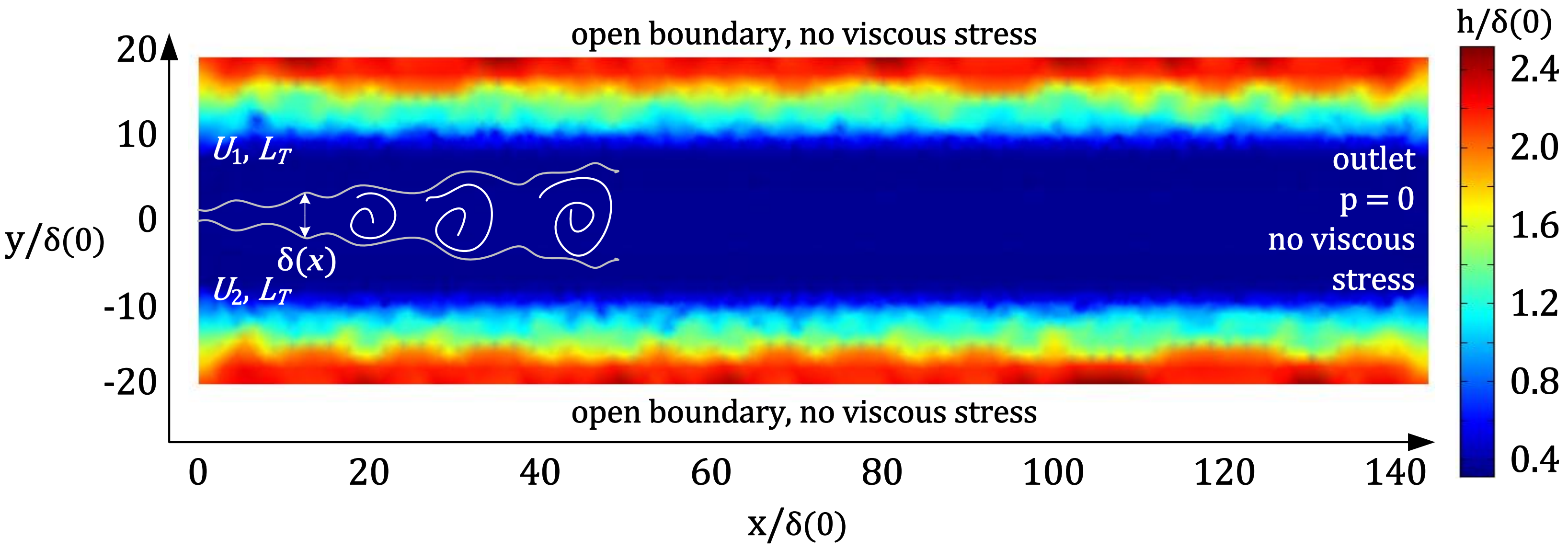
U_1

U_2

mean flow direction

$u(-y \to \infty) = \bar{U}_2$

x, i



Inlet fluctuating velocity

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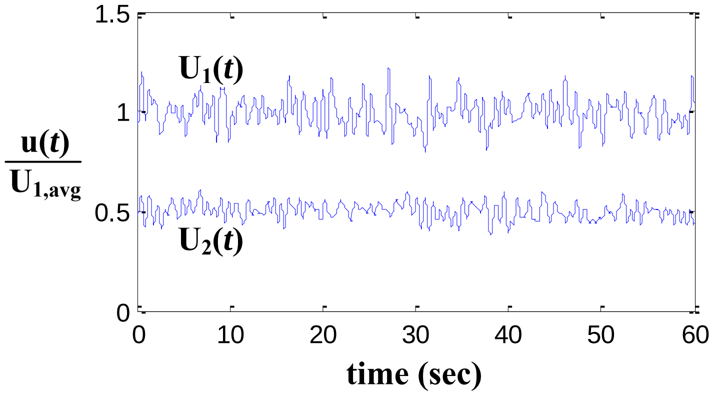
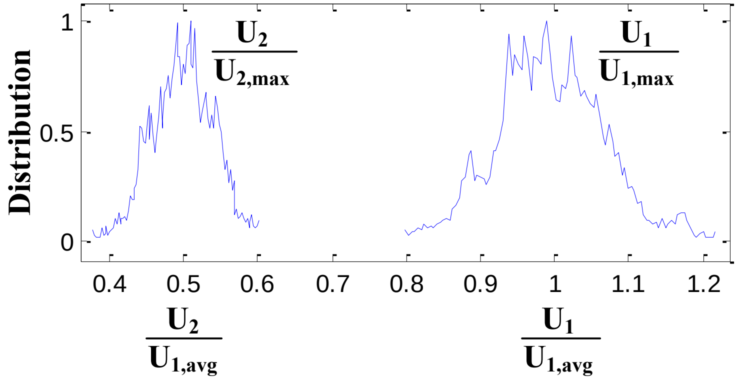
define $\Delta t, N, t_{final}, A_f, p_f, \overline{U_1}$
$\overline{U_2} = \frac{1}{2}\overline{U_1}$

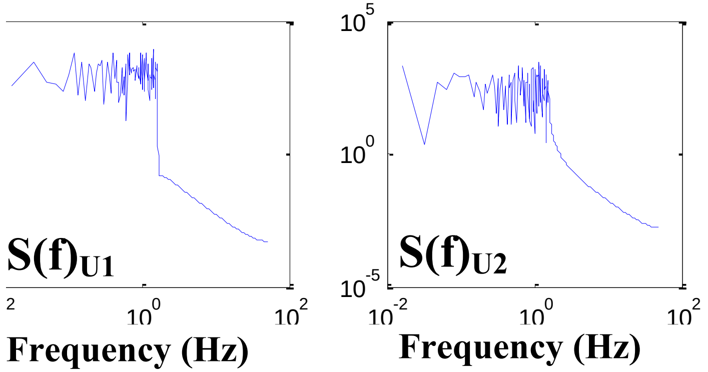
for $i = 1,2$
    $f_i = \frac{1}{p_f}\mathrm{rand}(1,N)$

    for $n = 1,2,\cdots,N$
        $U_i = U_i + (-1)^n\,\overline{U_i}A_f\sin(f_1(n)t)$
    next $n$

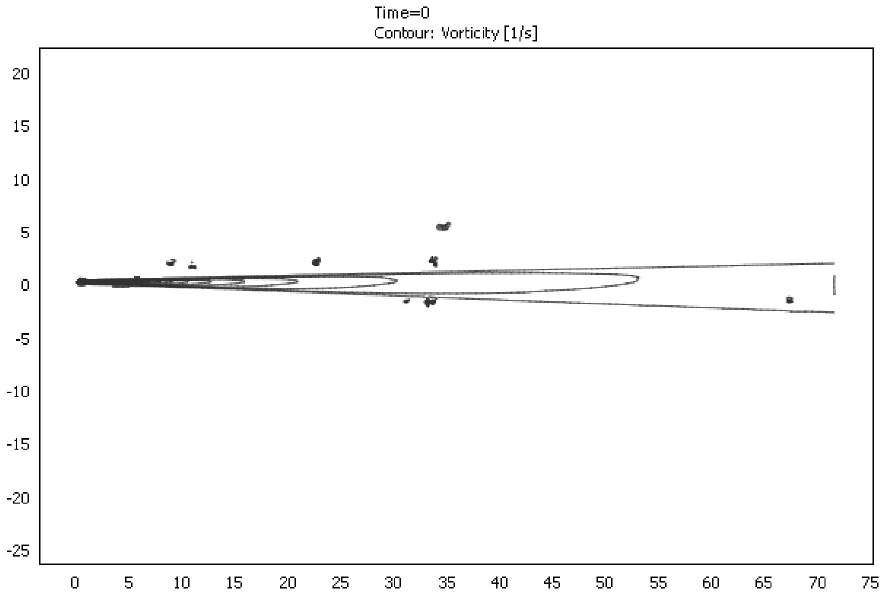
next $i$
```

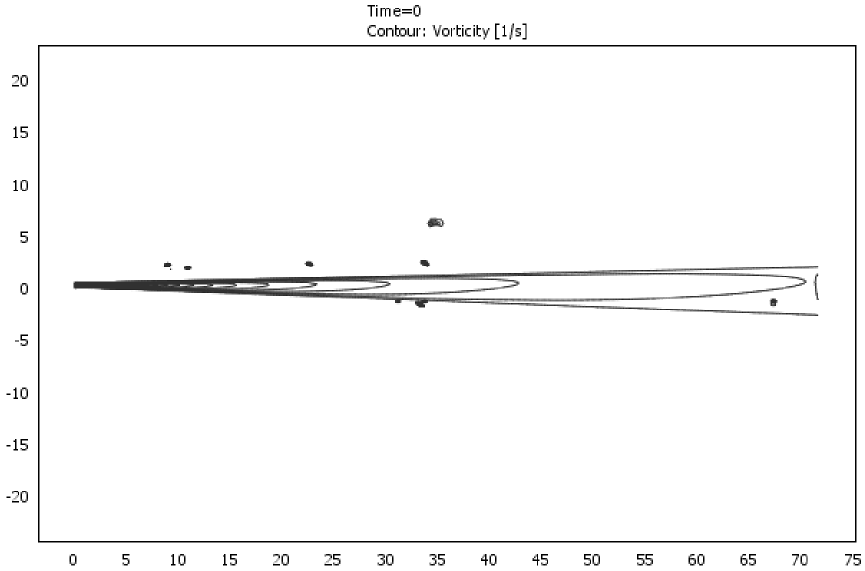


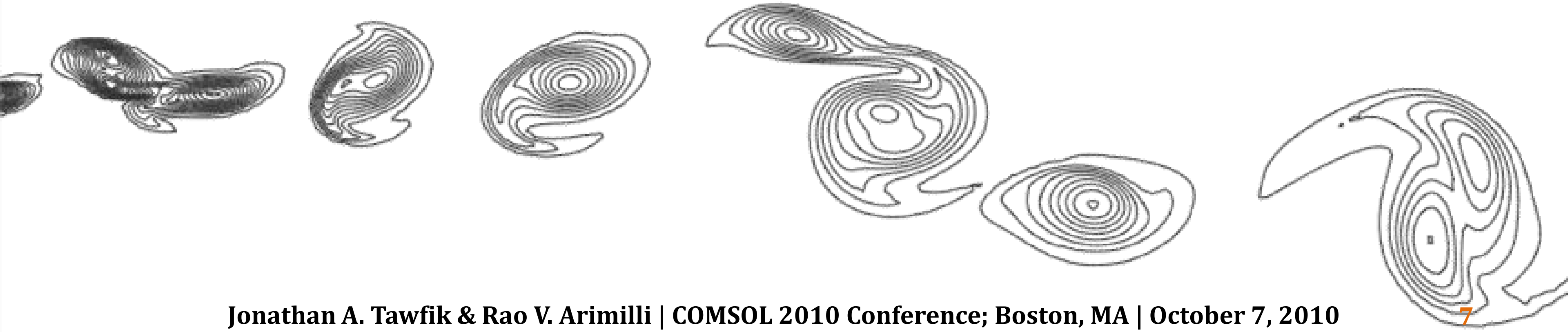




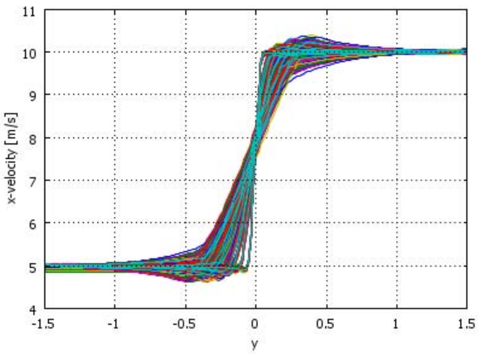
Results: Vorticity Contour. $-60 < \Omega < -0.5\ s^{-1}$

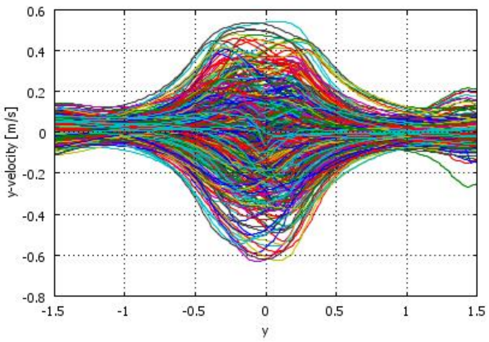


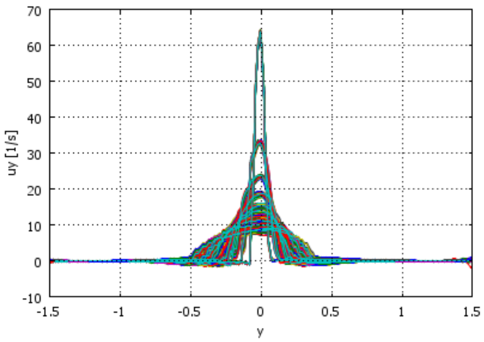


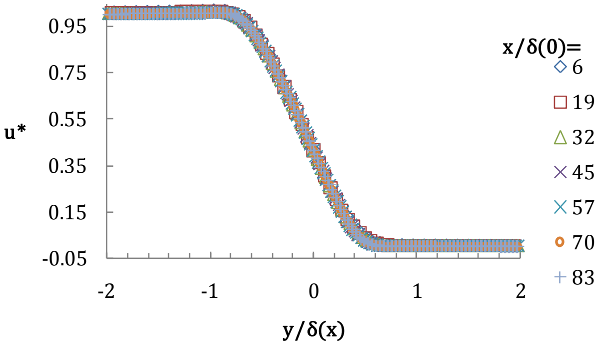


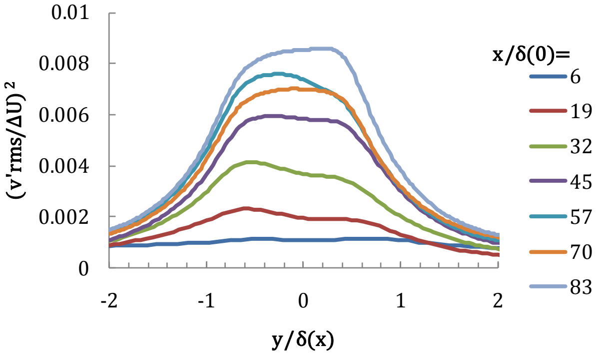
Results: Self-Similarity

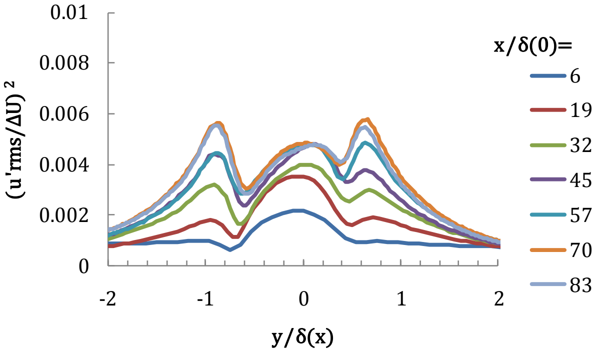












Conclusion

- A new approach to solving the classical two-stream turbulent mixing layer problem is demonstrated—
  - using the k-epsilon model of COMSOL 3.5a.
  - The problem is driven by superposed fluctuating velocities in the stream-wise direction at the inlet.
  - The randomized fluctuations are controlled by frequency and amplitude.

- Recommendations
  - Parametric study of frequency and amplitude
  - Boundary conditions in the k-epsilon model solution

Questions?

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