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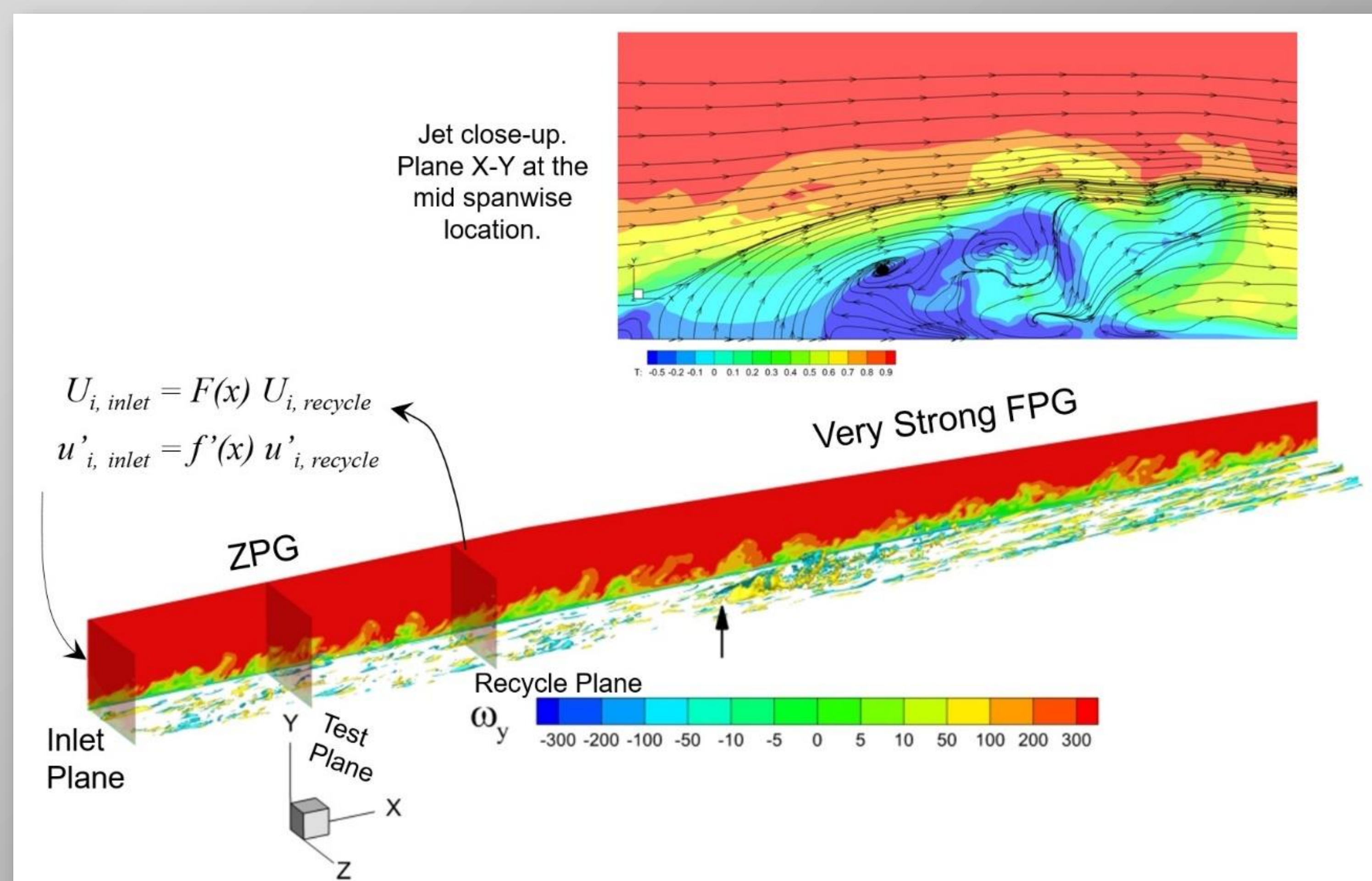
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## Introduction

Incompressible jets transversely issuing into a spatially developing turbulent boundary layer is one of the most challenging and crucial types of three dimensional flows due to its fluid-dynamic complexity and technological applications; for instance, film cooling of turbine blades, chimney plumes, fuel injection, etc.

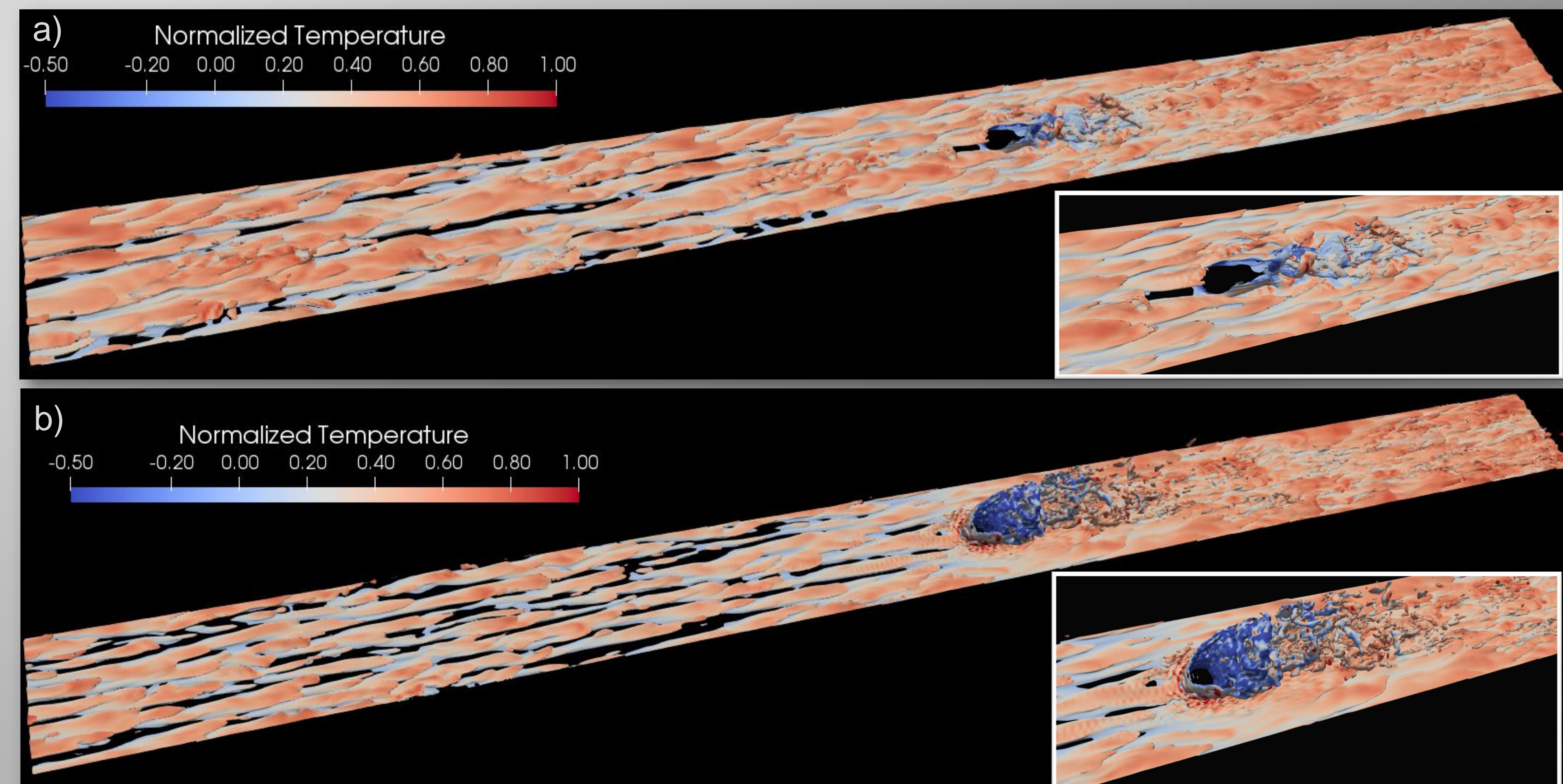
In this investigation, high spatial/temporal resolution Direct Numerical Simulation (DNS) of a cold jet in a crossflow under streamwise favorable pressure gradient (FPG) is performed. The goal is to accurately model the interaction between the wall-normal laminar jet with the incoming spatially-developing turbulent boundary layer in order to elucidate the physics behind the coherent structures in crossflow jets at low and high velocity ratios (VR = 0.5 and 2).

The analysis is done by prescribing accurate turbulent information (instantaneous velocity and temperature) at the inlet of a computational domain for simulations of spatially-developing turbulent boundary layers [1-3].

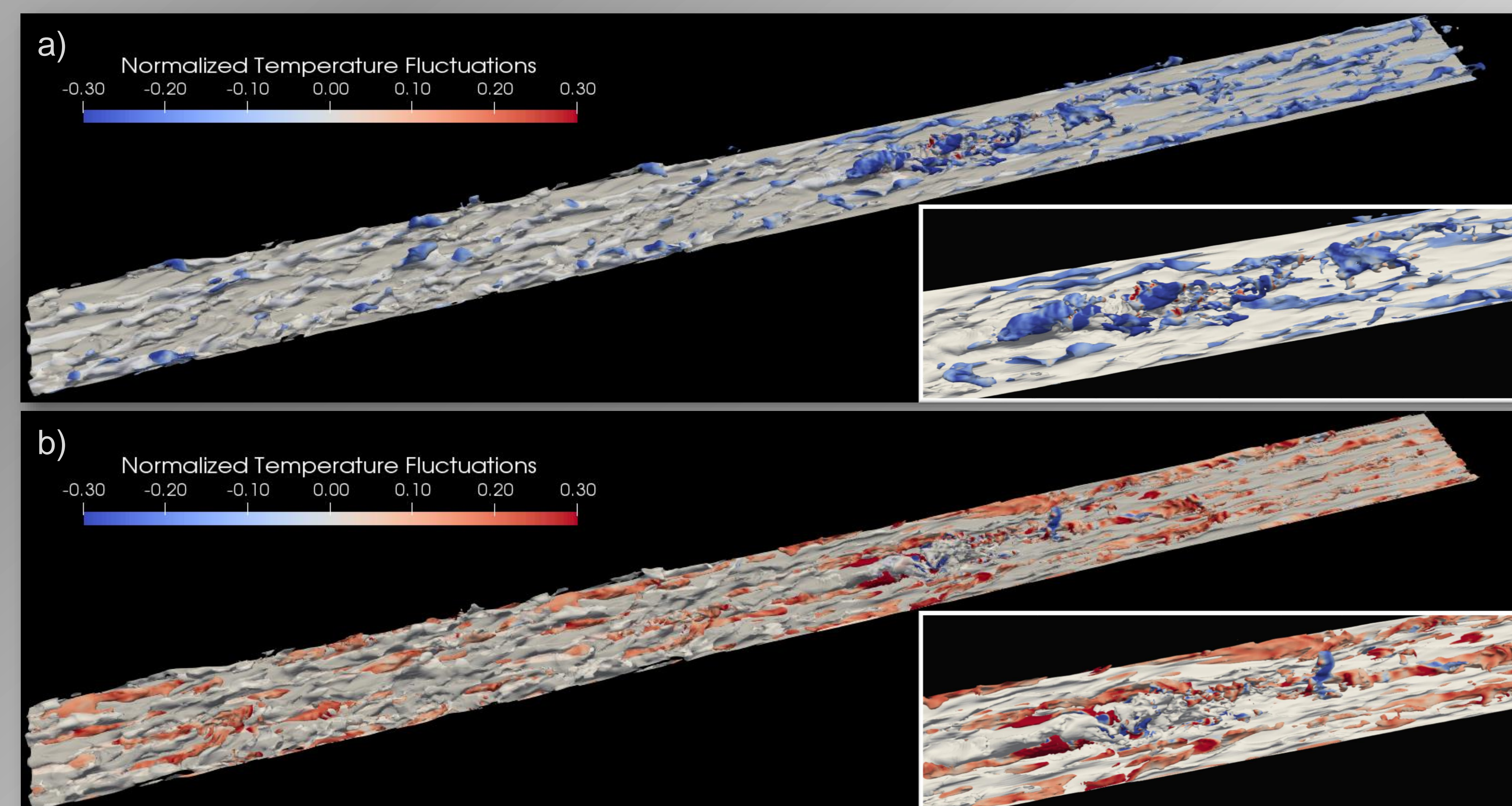


Schematic of the spatially-developing boundary layer with inlet, recycle and test planes about  $60 \delta_{\text{inlet}}$  in streamwise length. The top view shows a close-up of the crossflow jet.

## Flow Visualization



Iso-surfaces of vorticity magnitude colored by temperature (normalized temperature of jet = -0.5) for a) VR = 0.5 and b) VR = 2. Corresponding close-up images on the right corner.



Iso-surfaces of a) low-speed streaks  $u' \approx -0.15U_\infty$  and b) high-speed streaks  $u' \approx +0.15U_\infty$  colored by temperature fluctuations at VR = 0.5. Iso-surface of instantaneous streamwise velocity  $U \approx 0.7U_\infty$  (gray surface). Corresponding close-up images on the right corner.

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**References:** [1] Araya G., Castillo L. and Hussain F., The log behavior of the Reynolds shear stress in accelerating turbulent boundary layers, J. of Fluid Mechanics, Vol. 775, pp. 189-200, 2015. [2] Araya G., Castillo L., Meneveau C. and Jansen K., A dynamic multi-scale approach for turbulent inflow boundary conditions in spatially evolving flows, J. of Fluid Mechanics, Vol. 670, pp. 581-605, 2011. [3] Quinones C., Araya G. and Chen Y., Thermal transport in a crossflow jet subject to a very strong favorable pressure gradient. Procs. of ASME 2017 International Mechanical Engineering Congress and Exposition IMECE 2017, November 3-9, 2017, Tampa, USA.