Impact of Numerical Domain on Turbulent Flow Statistics: Scalings and Considerations For Canopy Flows.

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BACKGROUND AND OBJECTIVES

- Large Eddy Simulations (LES) of flow over cuboid arrays are widely utilized for examining surface morphology effects on turbulence statistics, exchange processes, and turbulence topology in urban canopies.
- LES serves as an approximation of reality, necessitating careful attention to computational model setup for an accurate representation of physical processes.
- Currently, there are no guidelines for determining ideal domain size in studying the Urban Boundary Layer (UBL) using open channel flow setup with LES.
- This study investigates the impact of numerical domain size on first and second-order turbulent flow statistics.
- This poster specifically examines the **impact of cross-stream aspect ratio (YAR)** of the domain in LES simulations. $YAR = L_2/L_3$

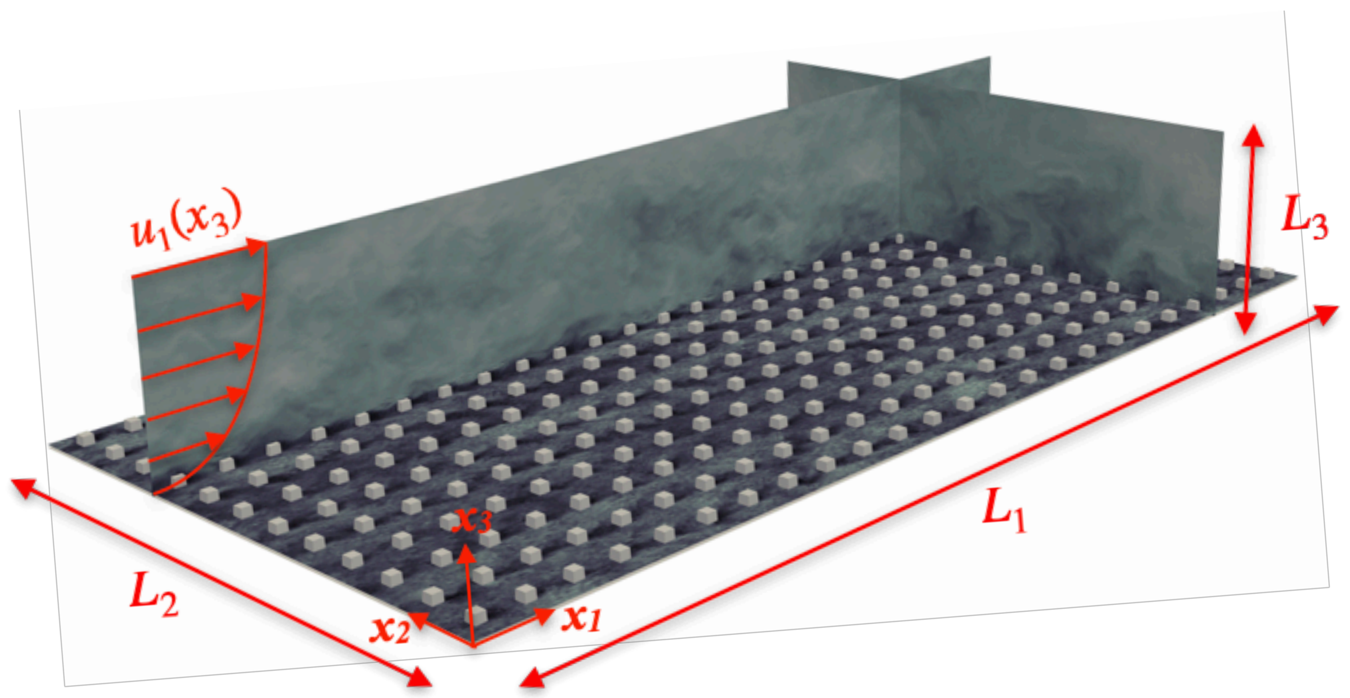

***Figure 1.** Visualization of LES of flow over cuboids.*

METHODOLOGY

- A suite of LES of flow over cuboid arrays is performed using a pseudo-spectral code.
- The domain's YAR is systematically varied for four different packing densities.

Packing Density (λ)	L_3/h	L_2/L_3	L_1/L_3
	16	1.5	6
0.25, 0.062,	16	3.0	6
0.028, 0.007	16	4.5	6
	16	6.0	6

***Table 1.** Suite of simulations. h is the height of cuboids.*

Preprint and data available at: beta.dpid.org/76
Please contact me at: as6481@columbia.edu

RESULTS

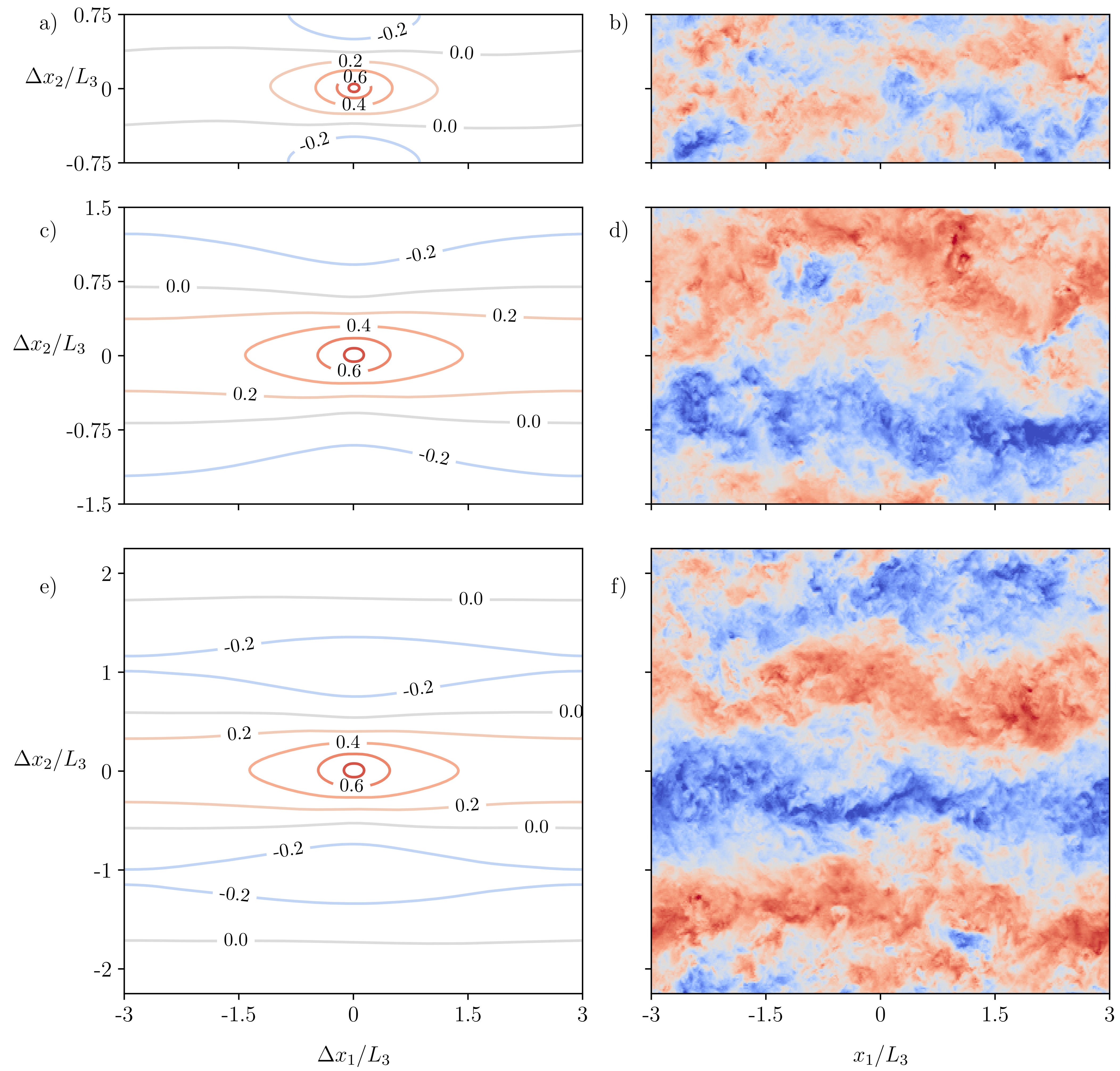

***Figure 2.** Two point correlation R_{11} contours (a, c, e) and streamwise instantaneous flow field fluctuations (b, d, f) for cases with packing density 0.028. The cross-stream aspect ratio is varied as: (a, b) 1.5, (c, d) 3.0, (e, f) 4.5.*

DISCUSSION

- **Figure 2**: Broader domains (d, f) exhibit both fast and slow turbulent streaks, contrasting with the absence in the narrower domain (b), reducing streamwise coherence (0.2 contour line).
- **Figure 3**: Narrow domain (YAR 1.5) predicts mean streamwise velocity within 2% of the widest domain across all layers and packing densities.
- **Figure 4**: Narrow domain can significantly underpredict (~15%) the mean streamwise variance, with satisfactory collapse observed beyond YAR 3.0.
- **Figure 5**: A decrease in the growth of cross-stream structures is observed in narrow domain.

RESULTS (cont'd)

Packing densities: (a) 0.25, (b) 0.062, (c) 0.028, (d) 0.007.
Lines - Red: YAR 1.5, Blue: YAR 3.0, Black: YAR 4.5, Brown: YAR 6.0

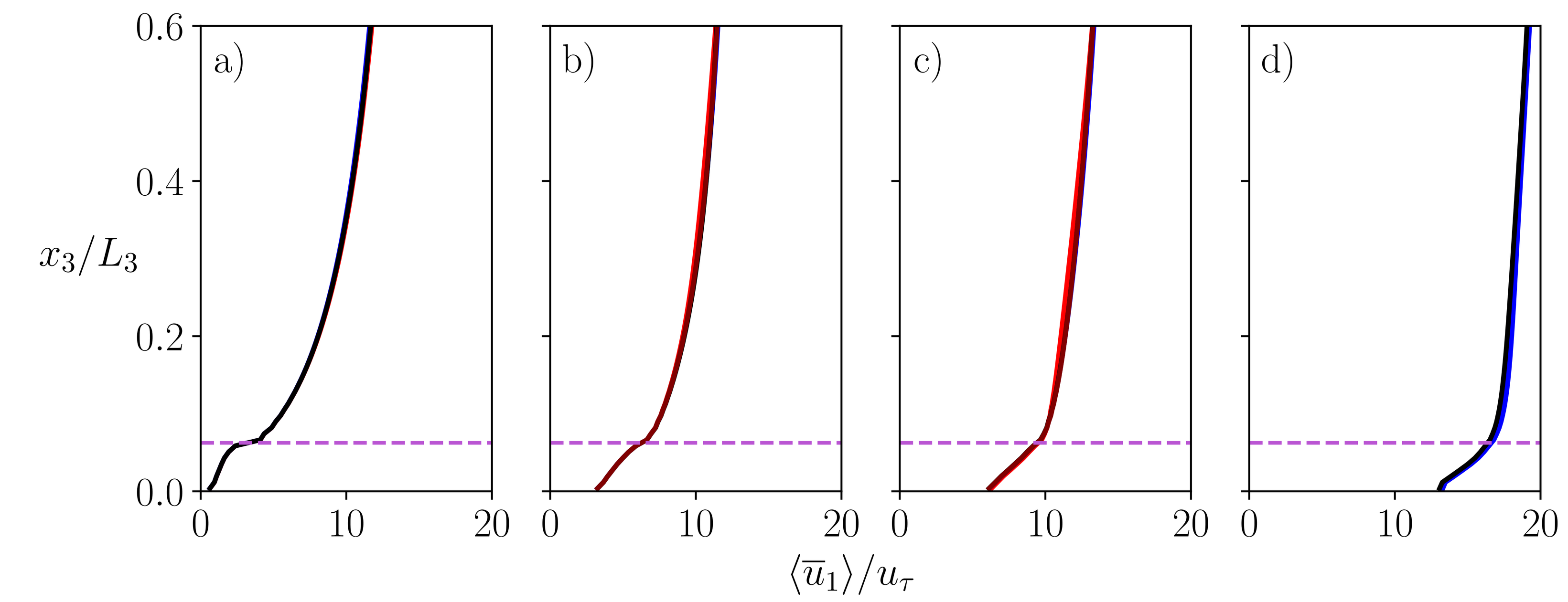

***Figure 3.** Mean streamwise velocity profiles.*

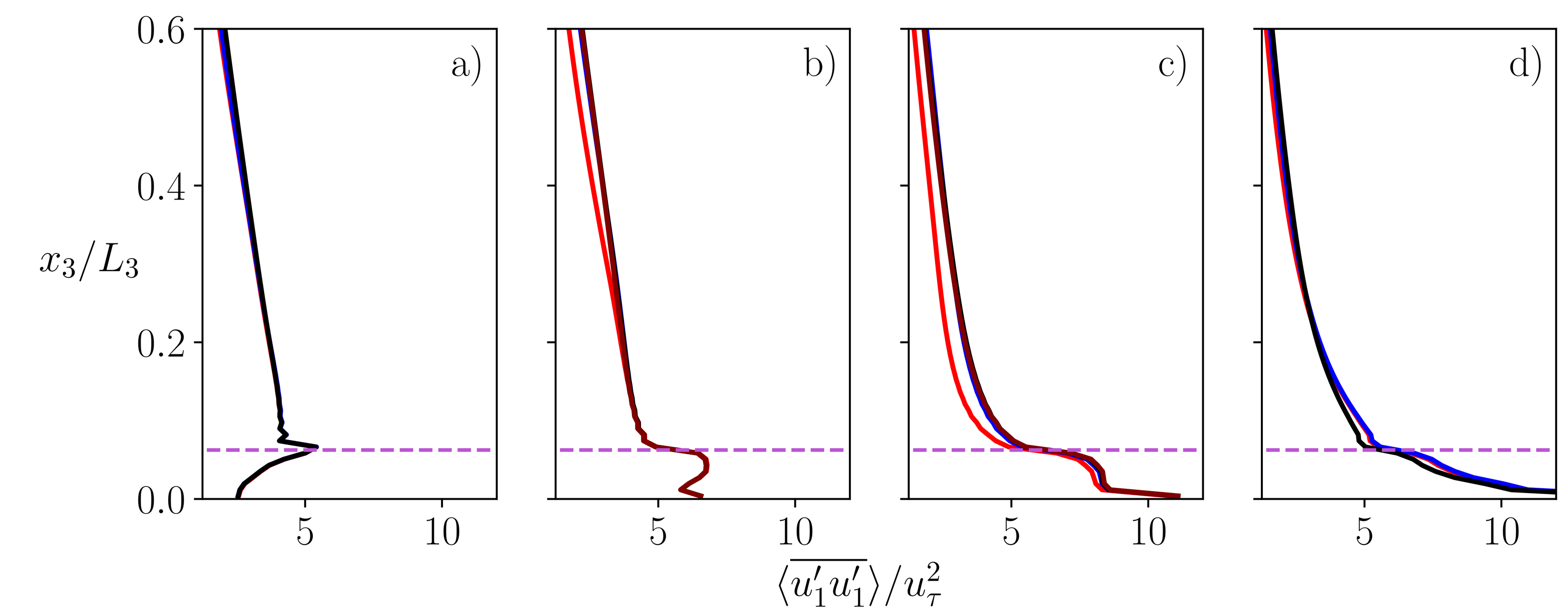

***Figure 4.** Mean streamwise variance profiles.*

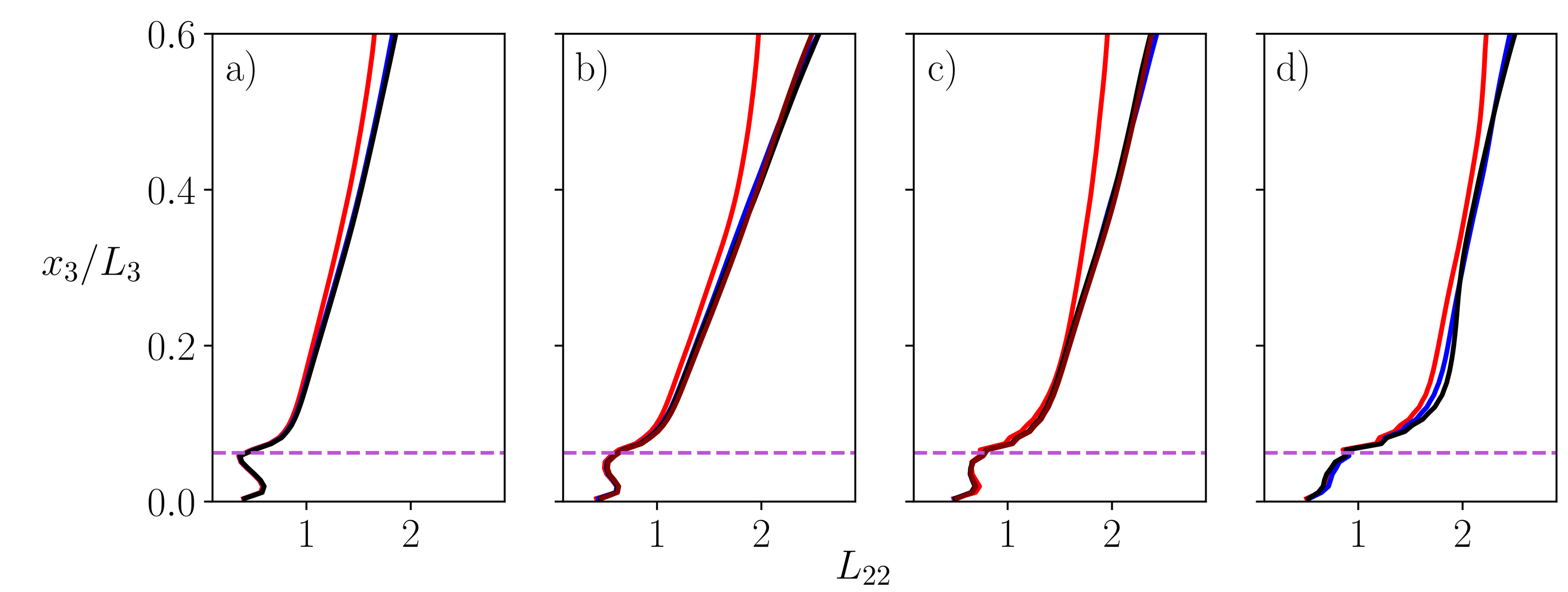

***Figure 5.** Transverse integral length scale profiles.*

CONCLUSION

- Domains characterized by YAR considerably below 3.0 can be inadequate to accommodate a pair of fast and slow turbulent streaks, thereby artificially destroying the growth of turbulent structures in the streamwise direction.
- Such domains also hinder cross-stream turbulent structure growth.