

Physical and Numerical Modeling of the Turbulent Flow Field Upstream of a Bridge Pier

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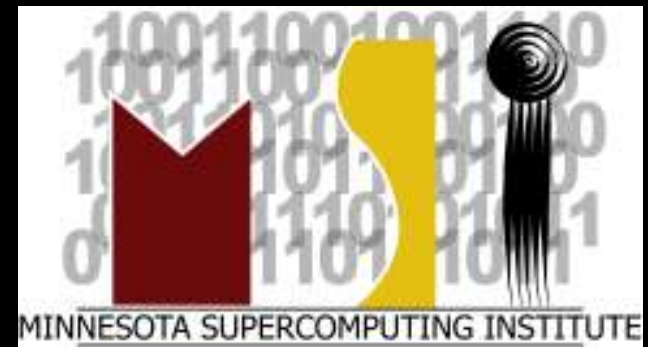
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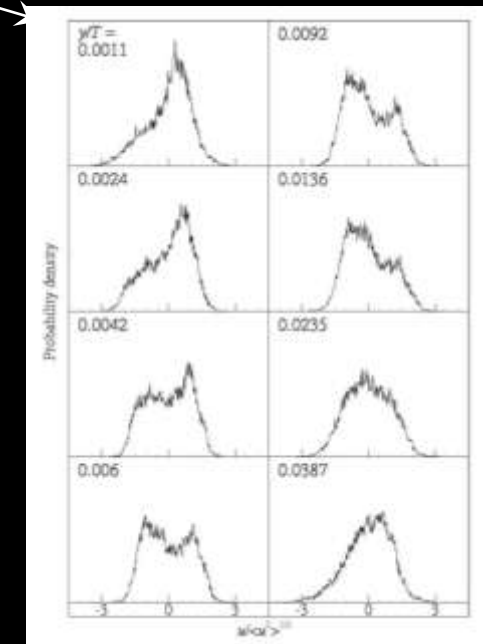
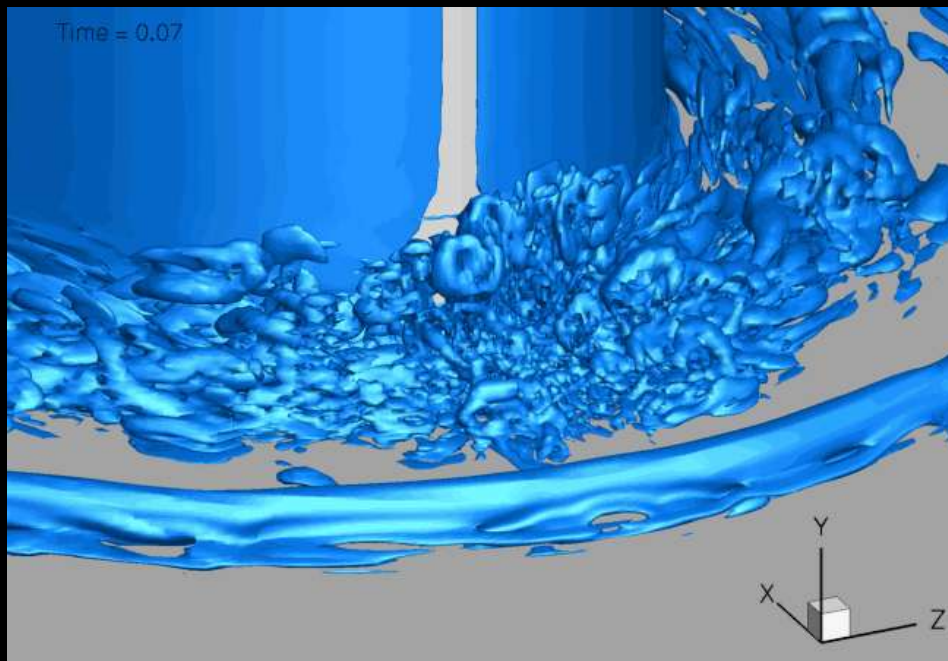
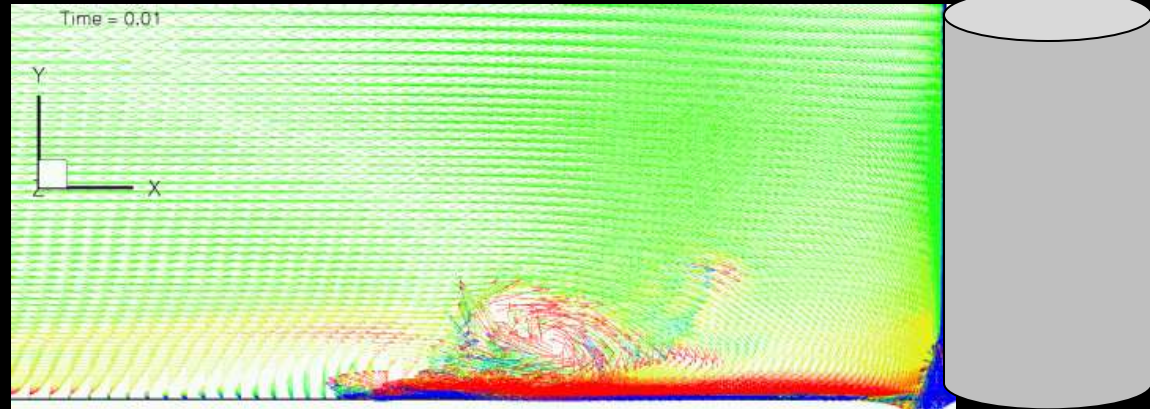
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On the bimodal dynamics of the turbulent horseshoe vortex

Paik, Escauriaza & Sotiropoulos, *Phys. of Fluids* 2007

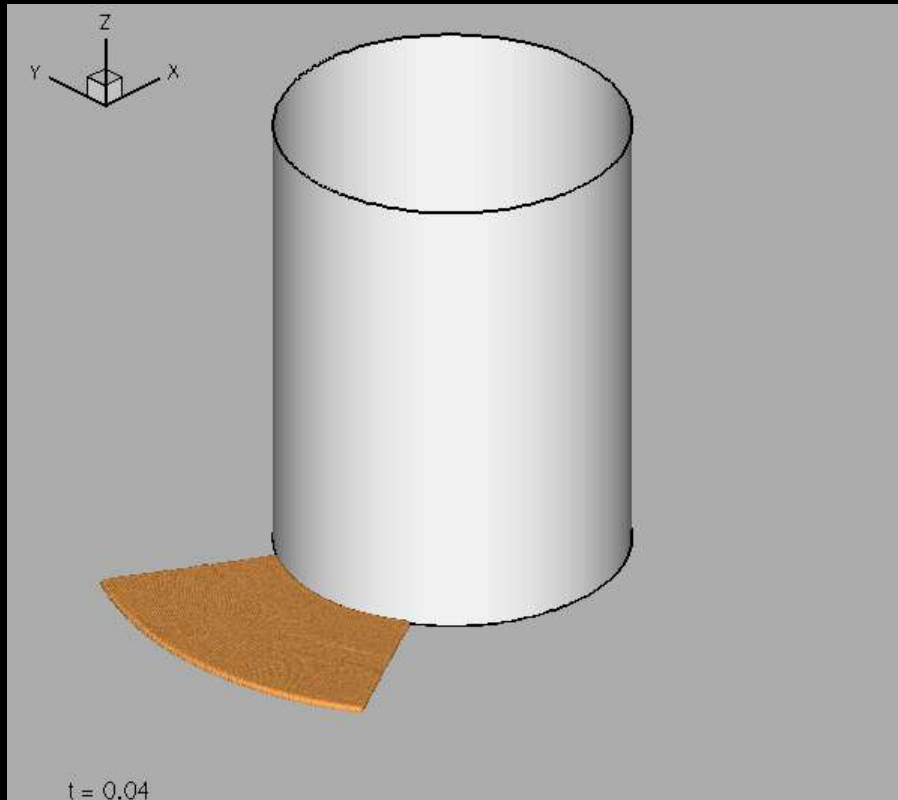
- Hybrid URANS/LES
- $Re=25,000$ to $125,000$
- Reproduced experiments by Devenport & Simpson (1990) and Dargahi (1990)



The physical mechanism of bimodal dynamics

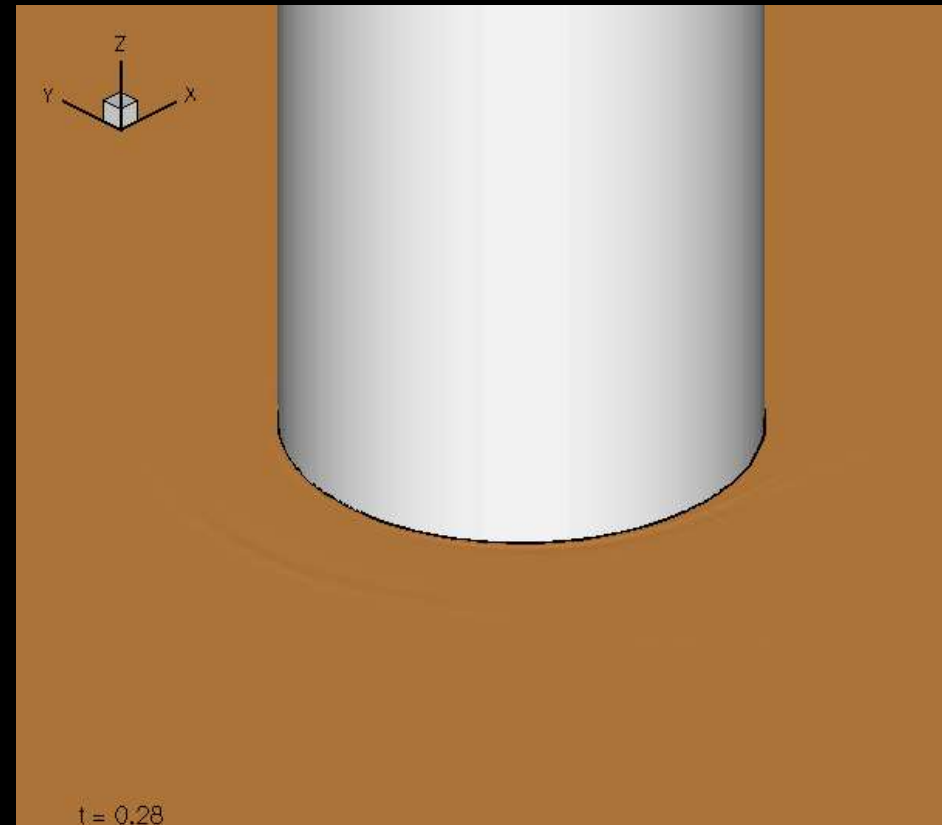
PDF of velocity fluctuations

Numerical simulation of sediment transport & scour



Lagrangian model of transport at the start of scour

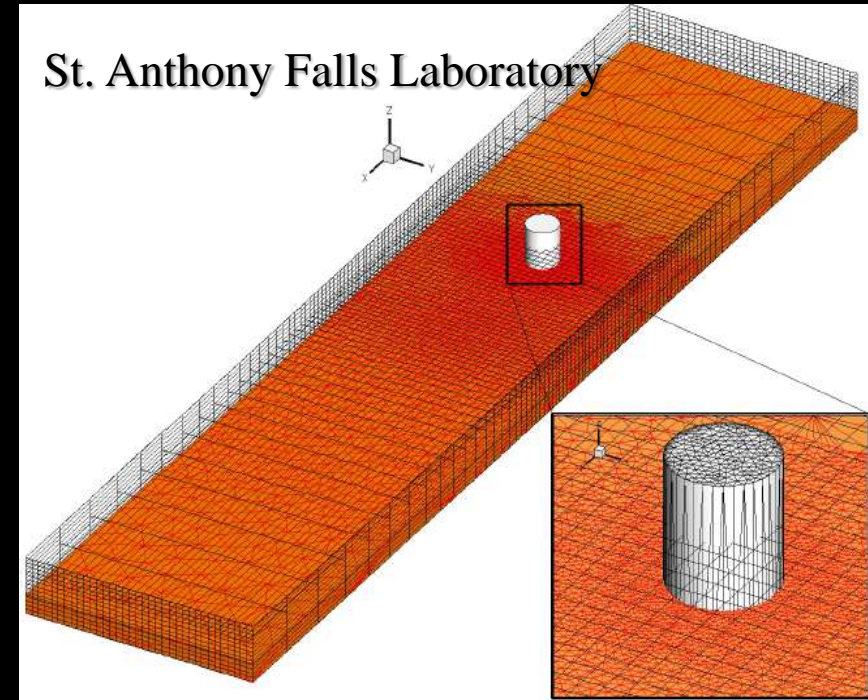
Escauriaza & Sotiropoulos
Journal of Fluid Mechanics, 2011



Bed-form dynamics in scour holes

Escauriaza & Sotiropoulos
J. Geophysical Research – Earth Surface, 2011

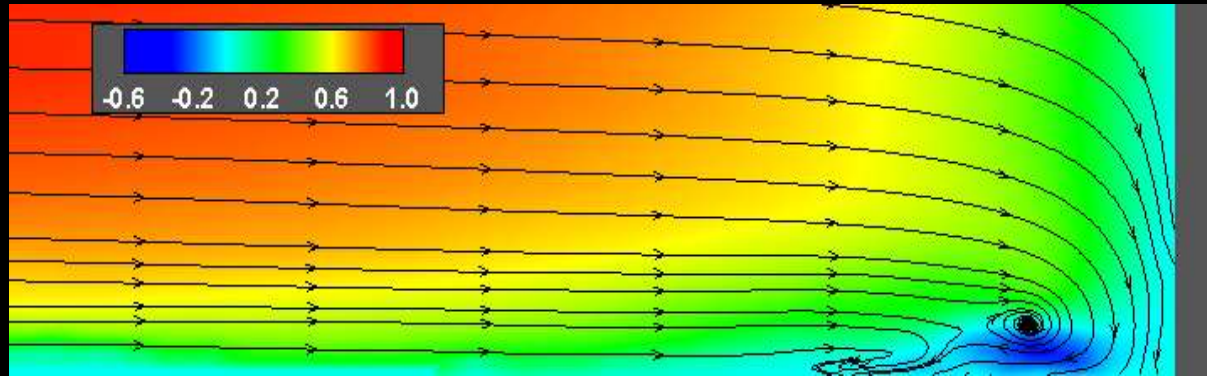
Objective: Integrate LES with high-resolution experimental techniques



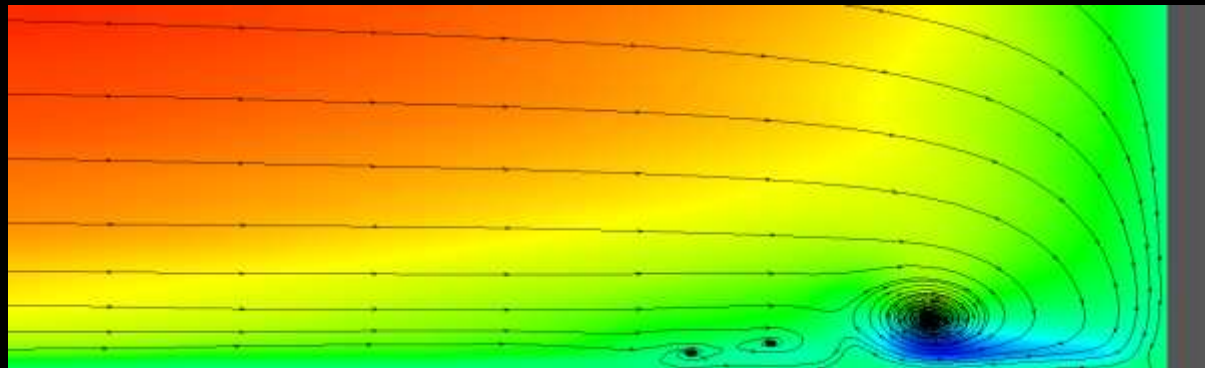
- Time-resolved PIV, 2D2C
- Continuous rate mode at 1000Hz
- $Re_D = \sim 25,000$ & $45,000$
- Sampling volume: $0.5 \times 0.5 \times 2.0$ mm
- Large-eddy simulation with the Curvilinear Immersed Boundary method (Kang et al. 2010)
- $Re_D = \sim 25,000$ & $45,000$
- Grid size: 14M to 40M nodes
- Fully turbulent inflow

Validation: Mean streamwise velocity ($Re=25,000$)

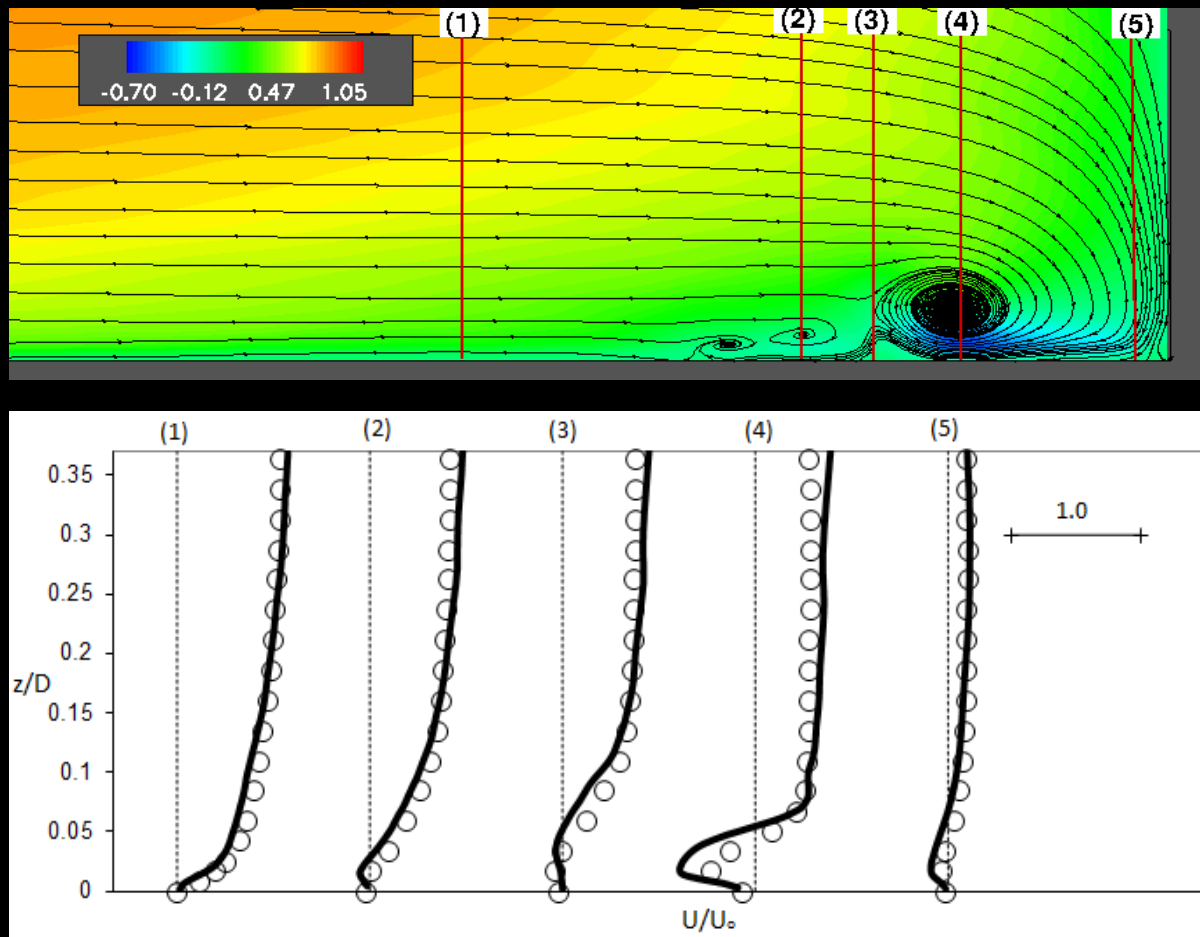
Experiment - PIV



Simulation - LES



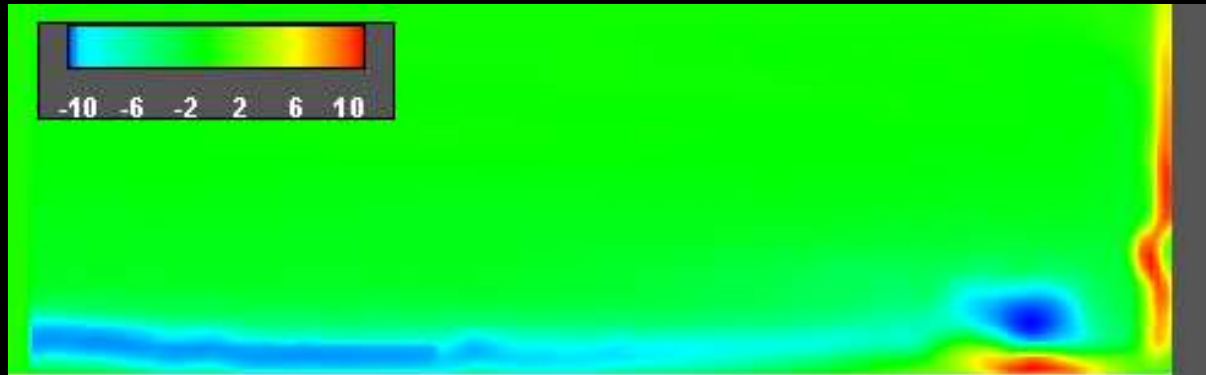
Validation: Mean streamwise velocity ($Re=25,000$)



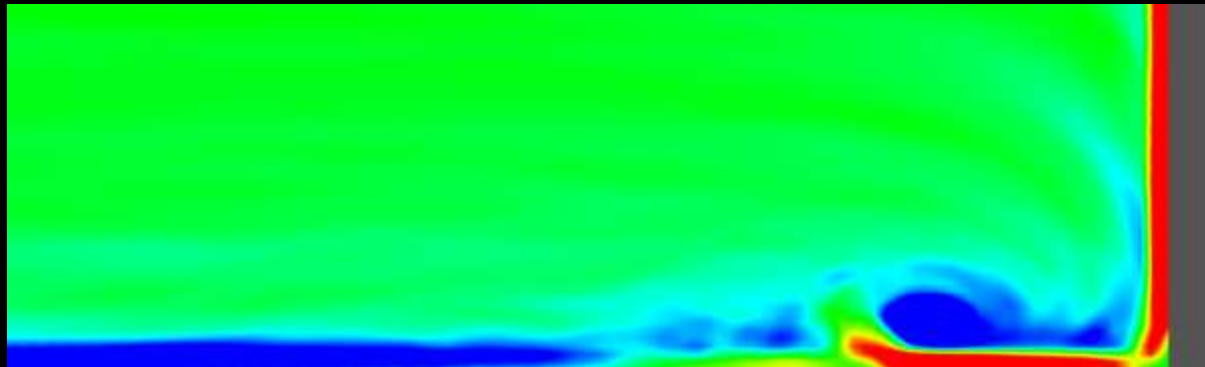
○ : Experiment - PIV
— : Simulation - LES

Validation: Mean out of plane vorticity ($Re=25,000$)

Experiment - PIV



Simulation - LES

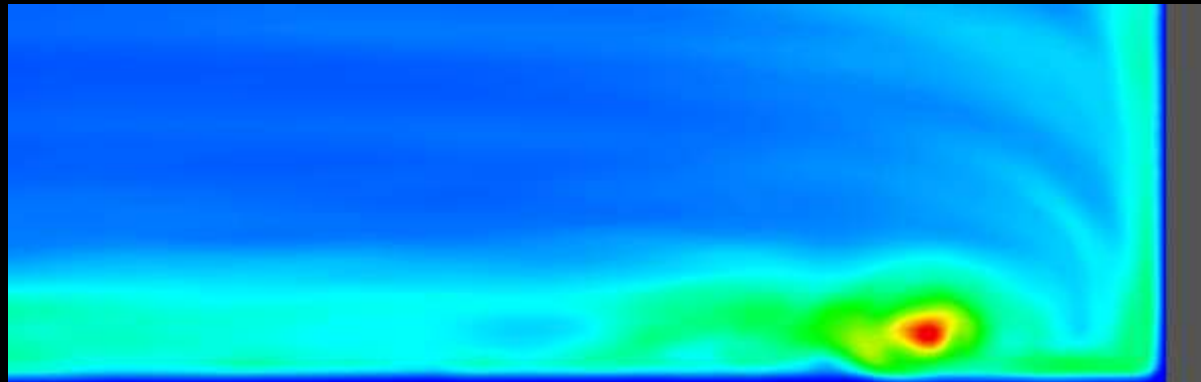


Validation: Turbulence kinetic energy ($Re=25,000$)

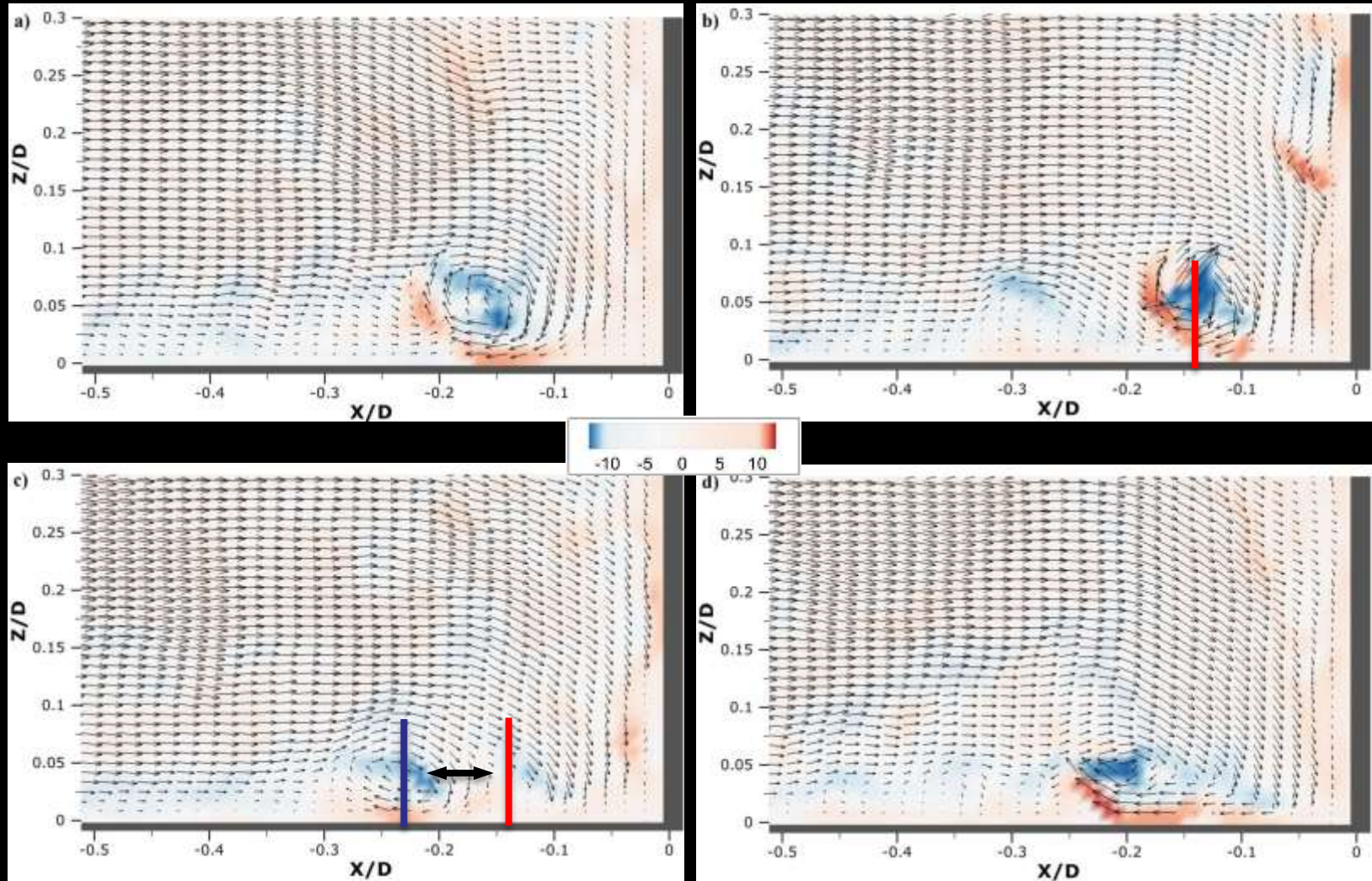
Experiment - PIV



Simulation - LES

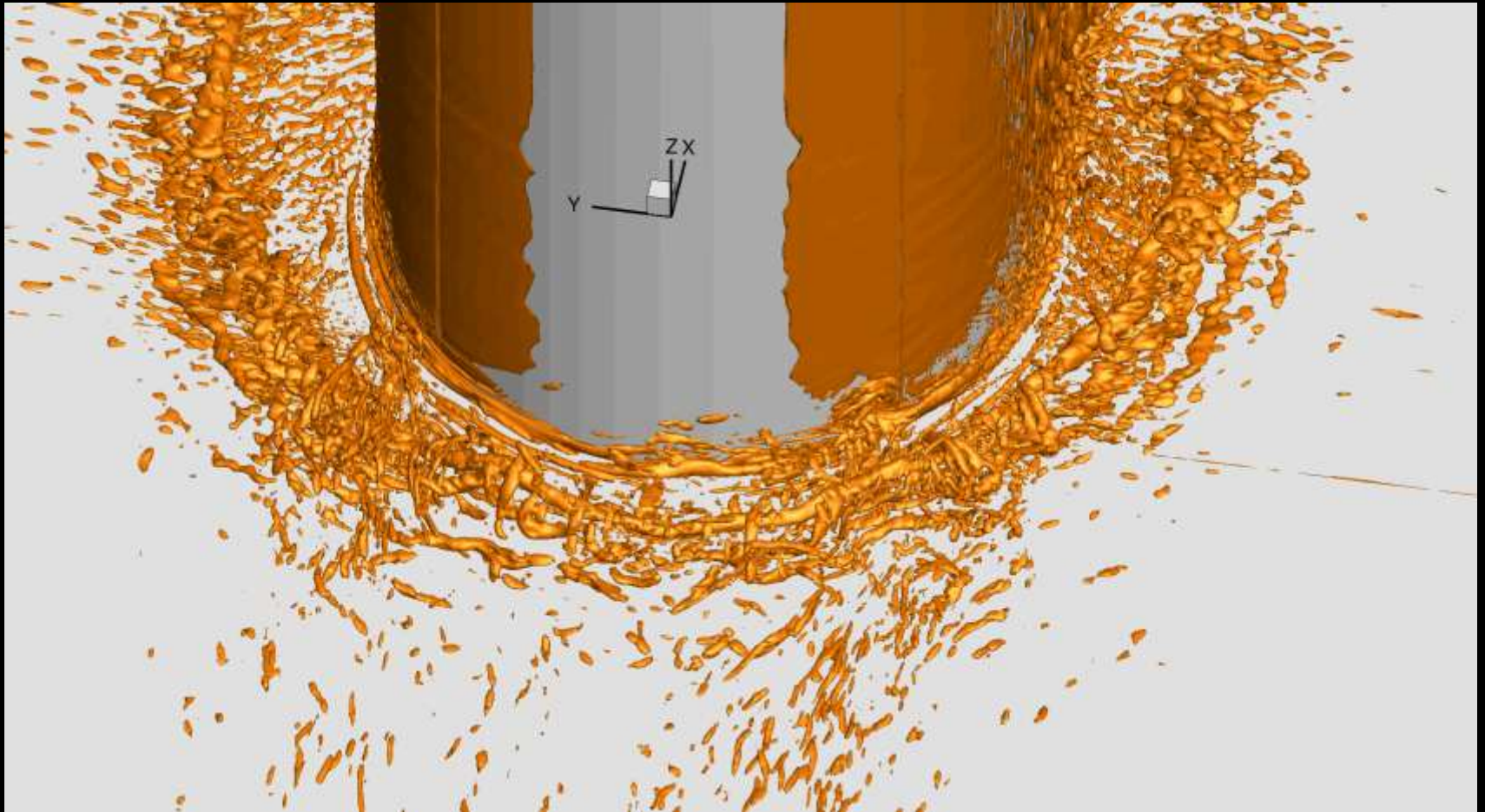


Experimental evidence of horseshoe vortex-wall interactions ($Re=25,000$)



Measured instantaneous velocity vectors and vorticity contours

Simulated (LES) 3D coherent dynamics of the horseshoe vortex



Conclusions & ongoing work

- High-resolution experiments coupled with LES elucidate the rich dynamics of the THV
- Vortex-wall interaction mechanism identified via coarse-resolution DES has been confirmed via high-resolution LES and PIV
- Ongoing work:
 - Systematically investigate Re effects
 - Mobile-bed experiments and simulations
 - Simulation of transport and erosion phenomena in natural waterways

