Model Predictive Control of Material Volumes with Application to Vortical Structures

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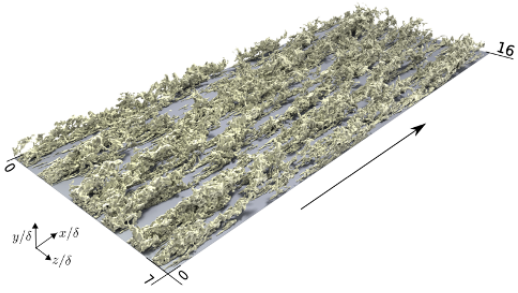
AIAA Journal, 2021

Large-Scale Motions in Turbulent Boundary Layers

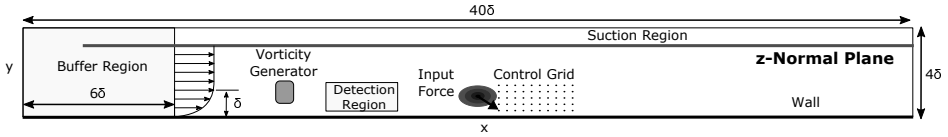
- Turbulent flows: dominated by motions with *temporal* and *spatial* coherence
- Outer region of turbulent boundary layers:
  - Dominated by large-scale and very large-scale motions (LSMs/VLSMs)
  - Bulges with sizes $\sim \delta$ (boundary layer thickness)
- LSMs contain:
  - $40 - 65\%$ of turbulent kinetic energy
  - $30 - 50\%$ of Reynolds shear stresses
  - Transport momentum
- Goal: Move LSMs toward the wall to increase near-wall mixing



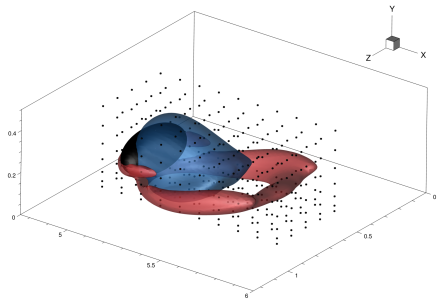
High streamwise velocity structures. (Sillero, J., PhD Thesis, 2014)

Moving Fluid Volumes using a Model-Based Controller*

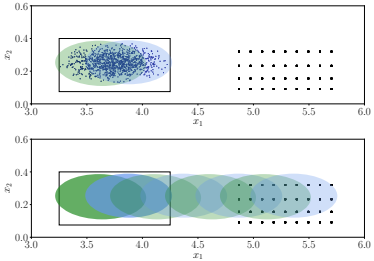
- Direct Numerical Simulation for targeting fluid volumes



- DMDcsp Model for flow dynamics



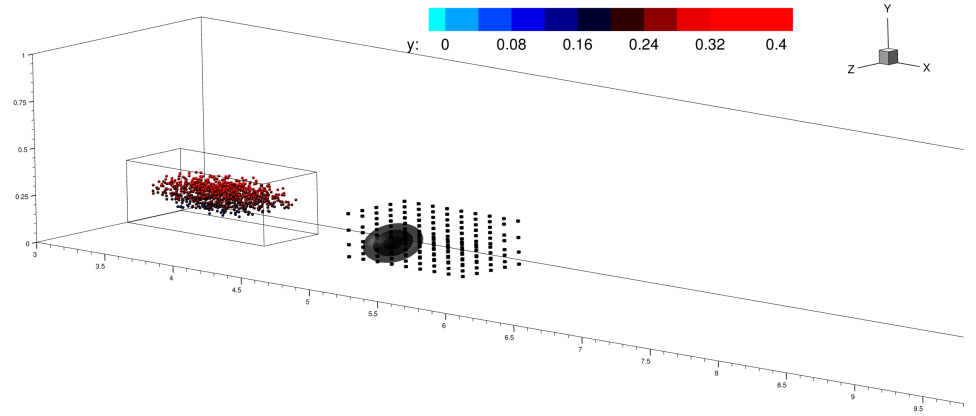
- Gaussian Mixture Model for targets



*A. Tsolovikos et al. ``Model Predictive Control of Material Volumes in Wall-Bounded Flows With Application to Vortical Structures''. In: *AIAA Journal, in press* (2021).

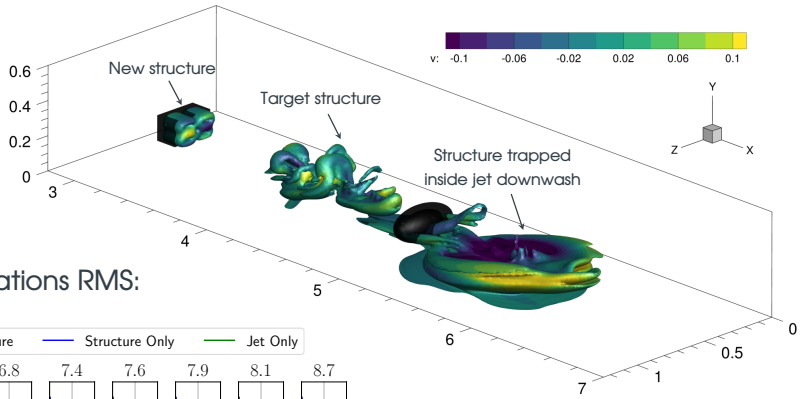
Model Predictive Control of Fluid Volumes

- Model Predictive Controller:
  1. Predict trajectory of target using GMM
  2. Find input that induces downwash at predicted target locations (optimal output tracking)

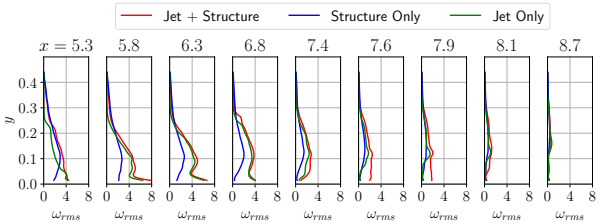


Model Predictive Control of Vortical Structures

- Targeting vortical structures instead of volumes results in increased near-wall mixing:



- Vorticity fluctuations RMS:



$\longrightarrow$ Near-wall mixing increases

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