Implementation and Assessment of High-Order Methods in the Framework of SU2

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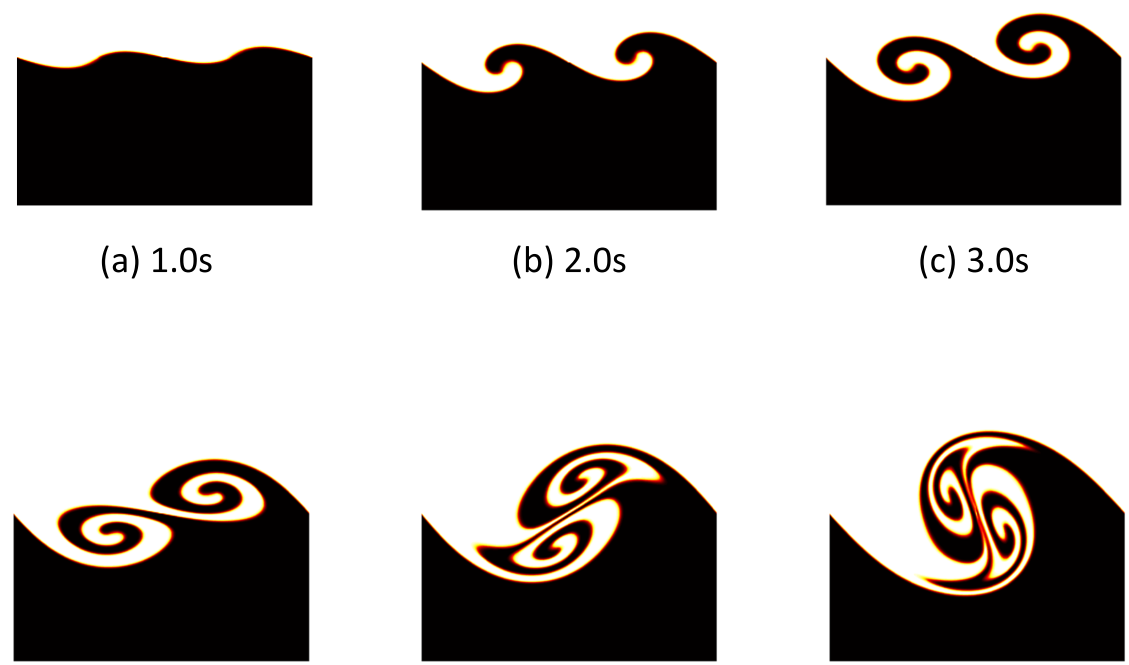
Presentation Outline

- Test Problem Definition: Double Vortex Pairing
- Numerical Schemes Assessed
  - 2nd and 3rd order MUSCL schemes within SU2 Finite Volume solver
  - 3rd order Discontinuous Galerkin method within SU2
- Performance Criteria
  - Vortex Evolution
  - Mach Number Effect
  - Momentum Thickness
  - Total Variation Bounded

Description of Problem: Double Vortex Pairing

- Mixing layer formed by two co-flowing streams of water
- Initial velocity perturbations inflate forming two distinct vortices
- Vortices roll around each other eventually merging to form one vortical structure
- Chosen as test problem due to presence of fine structures and discontinuities

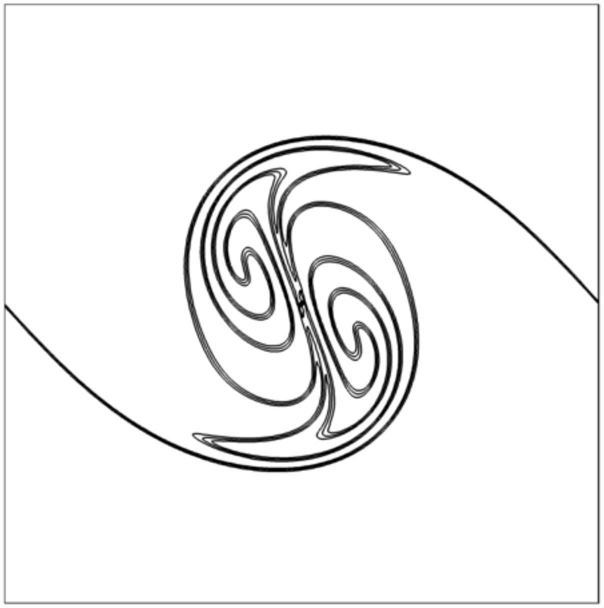


(a) 1.0s (b) 2.0s (c) 3.0s

(d) 4.0s (e) 5.0s (f) 6.0s

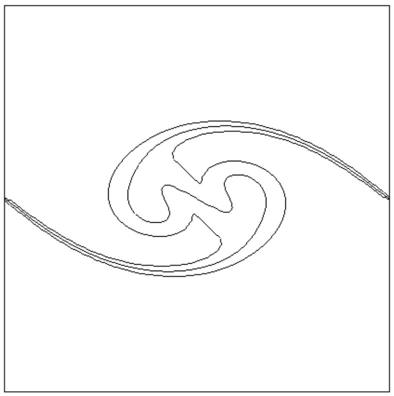
Double Vortex Pairing: Reference Solution

- Reference solution obtained using in-house code CNS3D
- Structured Grid Finite Volume solver
- 2nd to 11th order accurate MUSCL + WENO schemes
- 2nd to 4th order accurate time stepping Runge-Kutta schemes
- Used in previous journal publication investigating Double Vortex Pairing
- CNS3D used extensively in past for iLES/DNS simulations

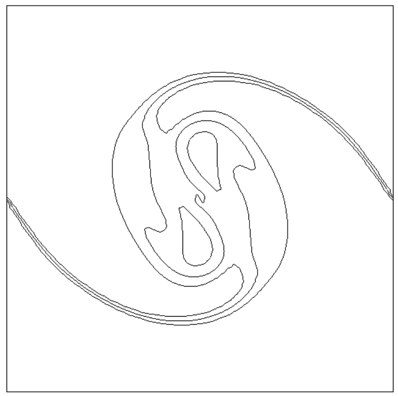


WENO 11th on 256x256 grid using CNS3D

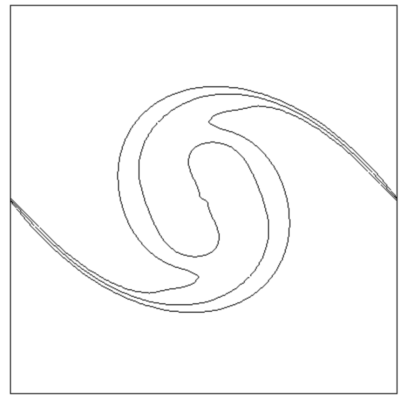
Double Vortex Pairing: 64x64 grid, M = 0.2



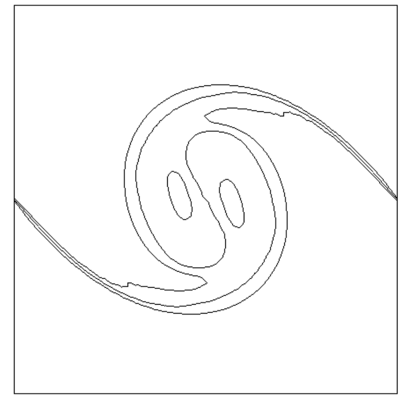
FV-M2



FV-M3



FV-M2-LMC



FV-M3-LMC

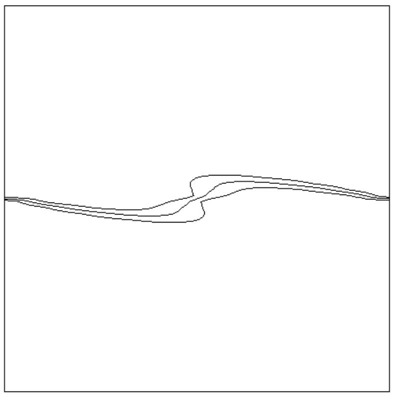
Settings (kept constant throughout):

- Classical RK4 Explicit Time Stepping
- Unsteady CFL = 0.3
- Riemann Solver: HLLC
- MUSCL 2nd order uses the Venkatakrishnan Limiter
- MUSCL 3rd order uses the Drikakis-Zoltak Limiter
- Passive Scalar Contour Lines: PS =0.25,0.5,0.75
- Reynolds Number = 1600

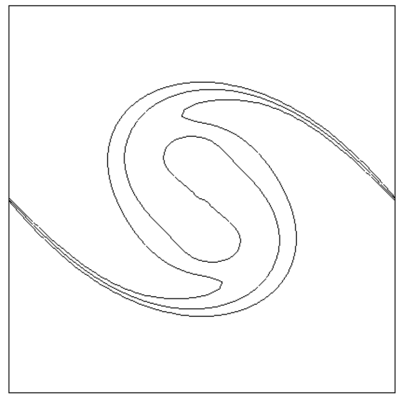
Nomenclature:

- FV = Finite Volume
- M2 = MUSCL 2nd order
- M3 = MUSCL 3rd order
- LMC = Low Mach Correction
- M = Mach Number

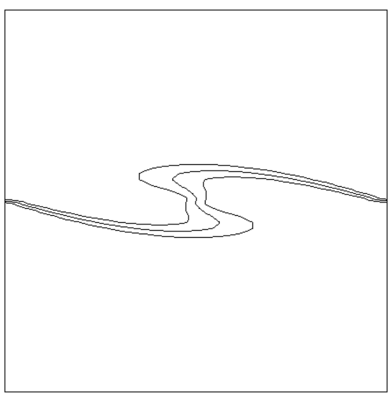
Double Vortex Pairing: 64x64 grid, M=0.02



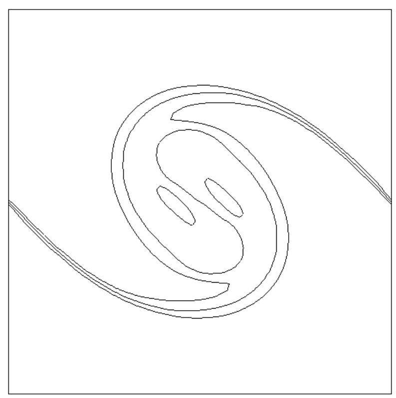
FV-M2, k = 0.0



FV-M2-LMC



FV-M2, k = 1/3

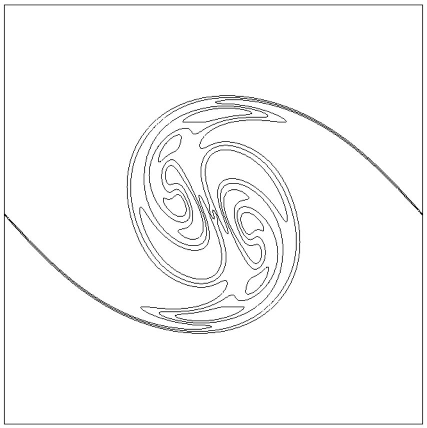


FV-M3-LMC

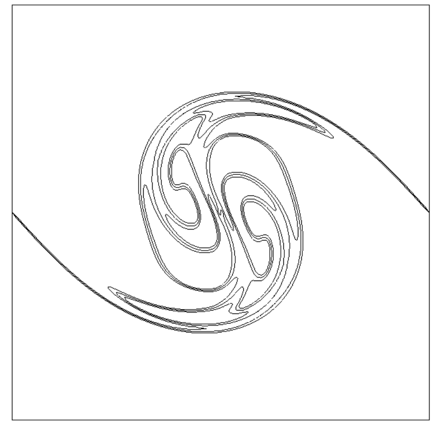
Nomenclature:

- FV = Finite Volume
- M2 = MUSCL 2nd order
- M3 = MUSCL 3rd order
- LMC = Low Mach Correction
- k = Limiter Coefficient

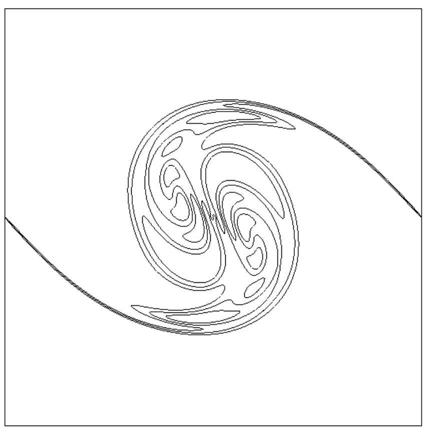
Double Vortex Pairing: 256x256 grid, M=0.2



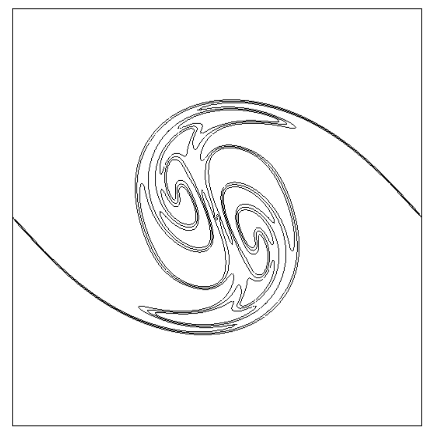
FV-M2



FV-M3

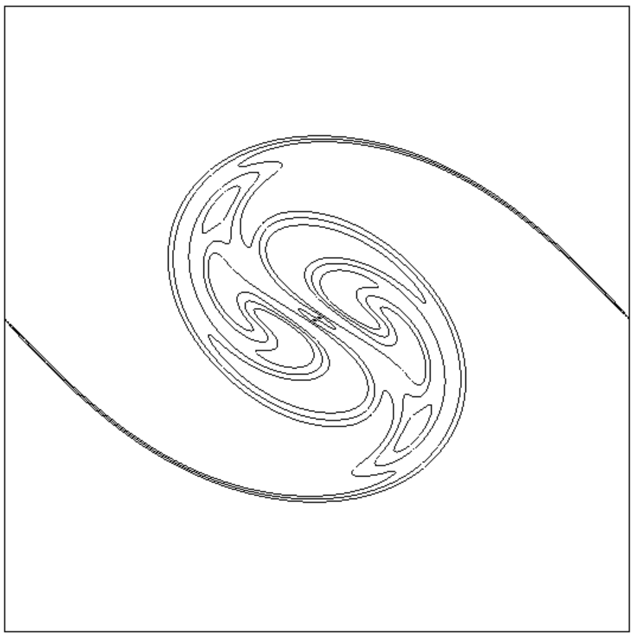


FV-M2-LMC

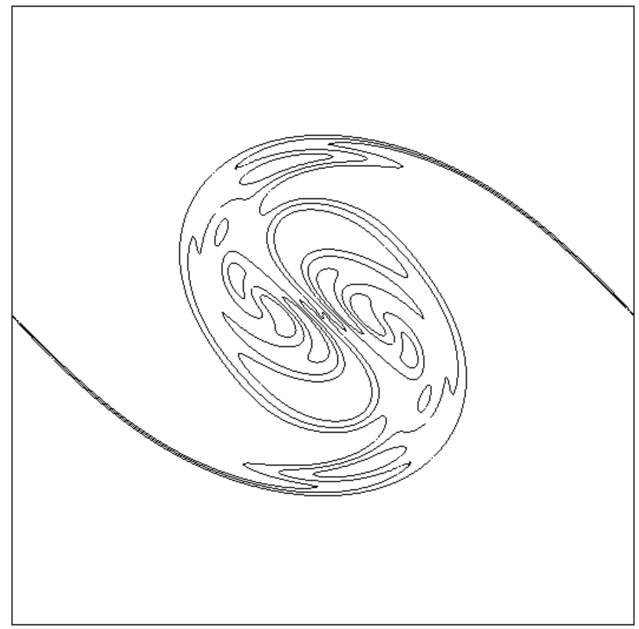


FV-M3-LMC

Double Vortex Pairing: 256x256 grid, M=0.02

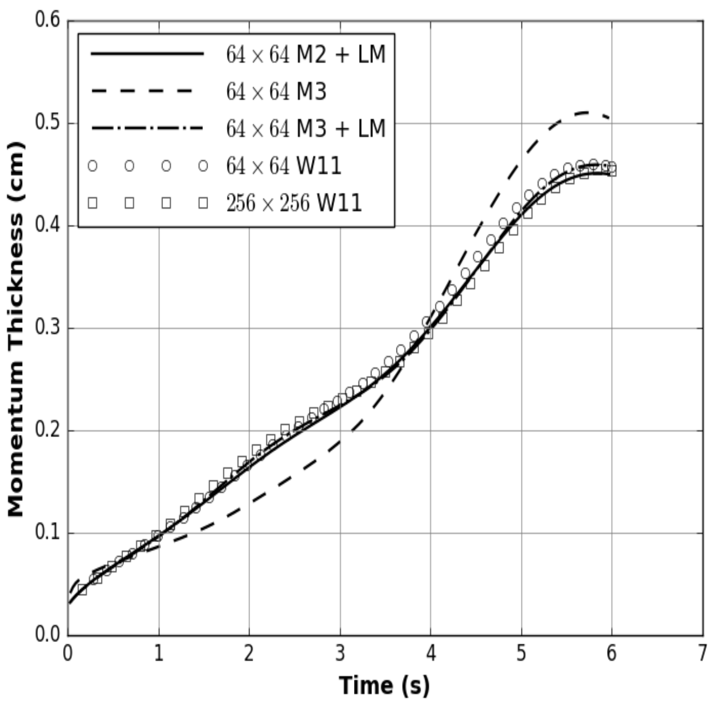


FV-M2

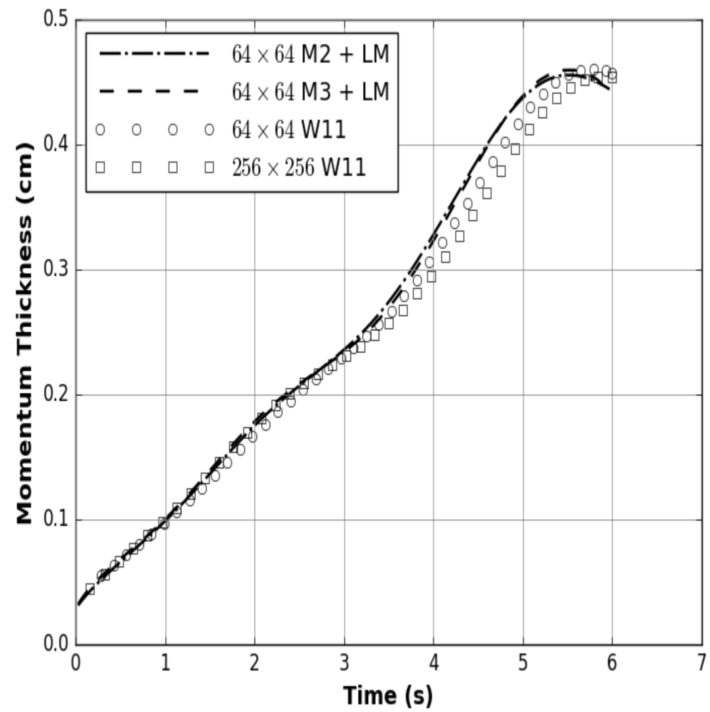


FV-M2 + LM

Double Vortex Pairing: Momentum Thickness

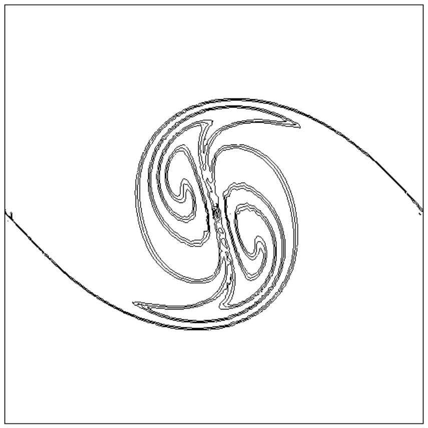


(a) M = 0.2

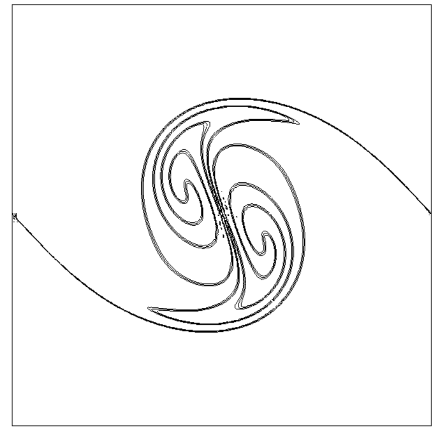


(b) M = 0.02

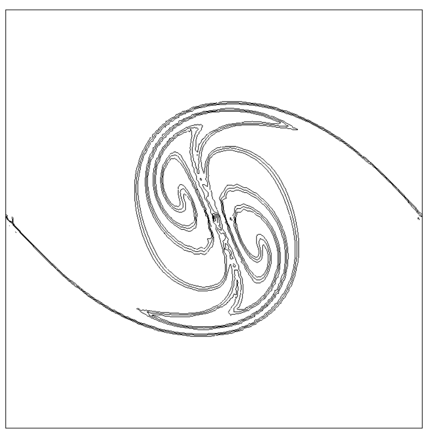
Discontinuous Galerkin 3rd Order



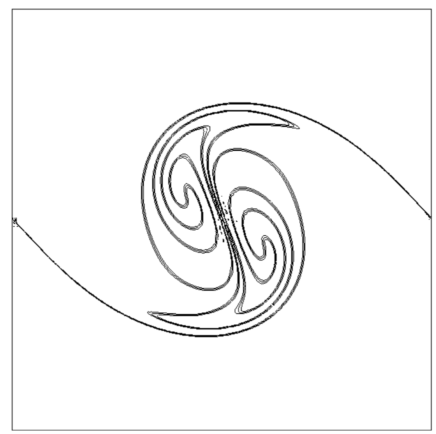
(a) M = 0.2, 64x64



(b) M = 0.2, 128x128

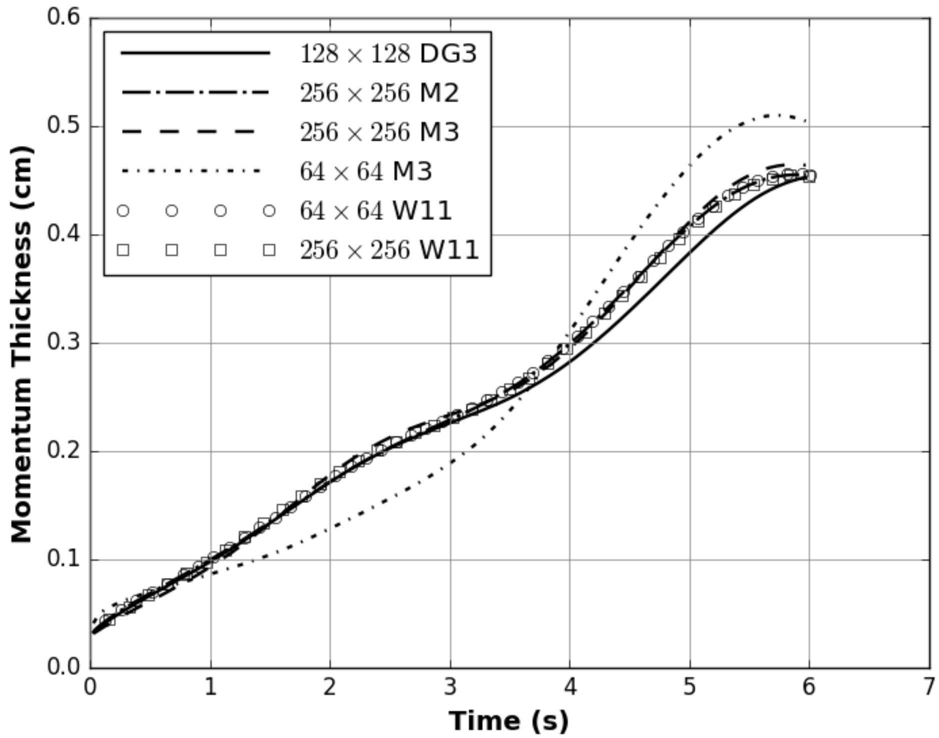


(c) M = 0.02, 64x64

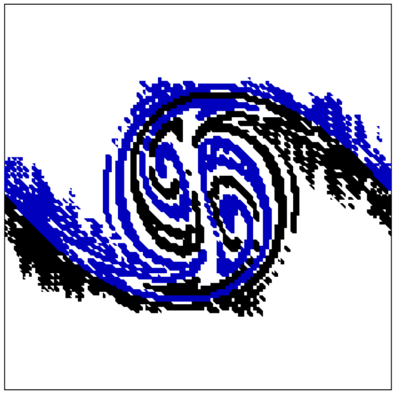


(d) M = 0.02, 128×128

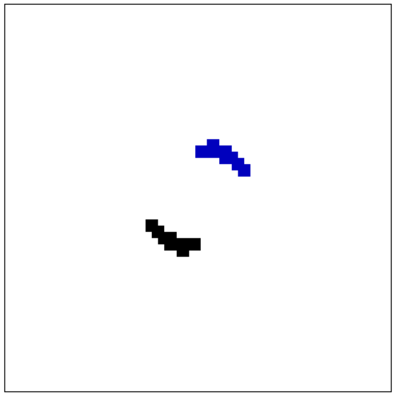
Double Vortex Pairing: Momentum Thickness



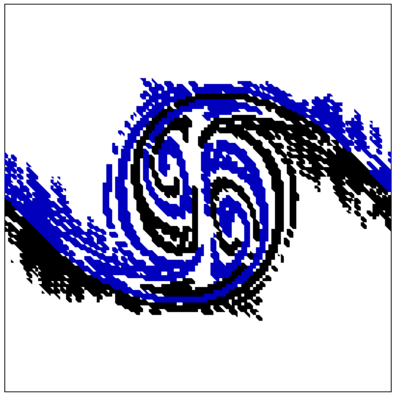
3^{rd} order Discontinuous Galerkin - TVB issues on 64x64 grid



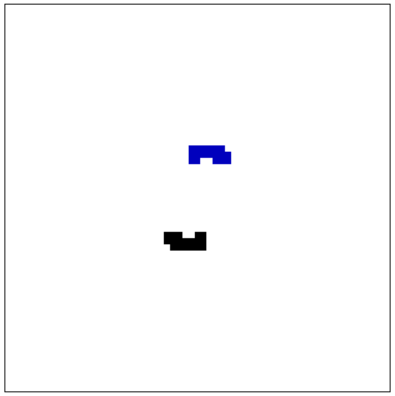
(a) 3^{rd} order DG, M = 0.2



(b) 11^{th} order WENO-FV, M = 0.2

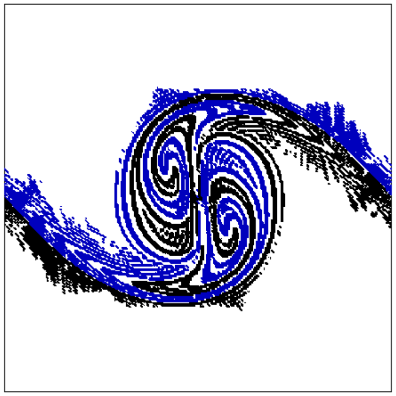


(c) 3^{rd} order DG, M = 0.02

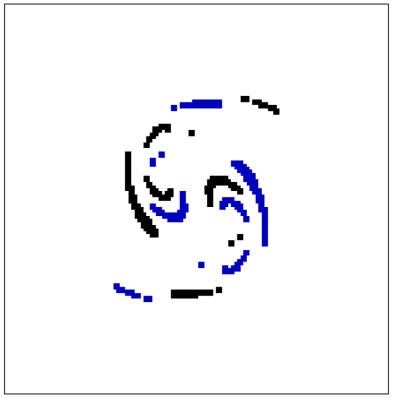


(d) 11^{th} order WENO-FV, M = 0.02

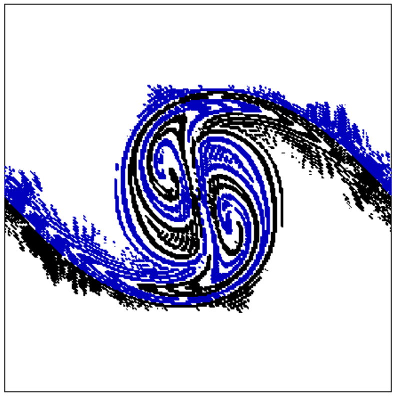
3^{rd} order Discontinuous Galerkin - TVB issues on 128x128 grid



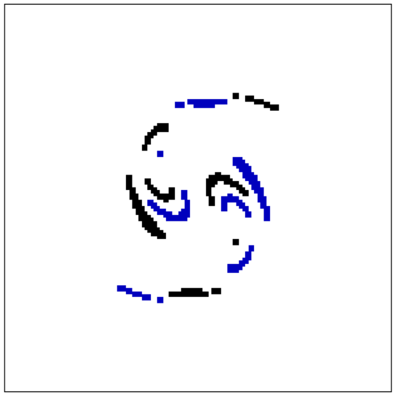
(a) 3^{rd} order DG, M = 0.2



(b) 11^{th} order WENO-FV, M = 0.2



(c) 3^{rd} order DG, M = 0.02



(d) 11^{th} order WENO-FV, M = 0.02

Conclusions

- Addition of LMC greatly improved results of the FV within SU2.
- 3^{rd} order accurate DG scheme produced results with sharper resolution than its FV counterparts.
- The 3^{rd} order DG scheme captures the non-linear behavior of the mixing layer, as well as converges to a final momentum thickness agreeable with the FV solver.
- 3^{rd} order DG scheme contained regions of flow with over/undershoots when compared to 11^{th} order WENO scheme.