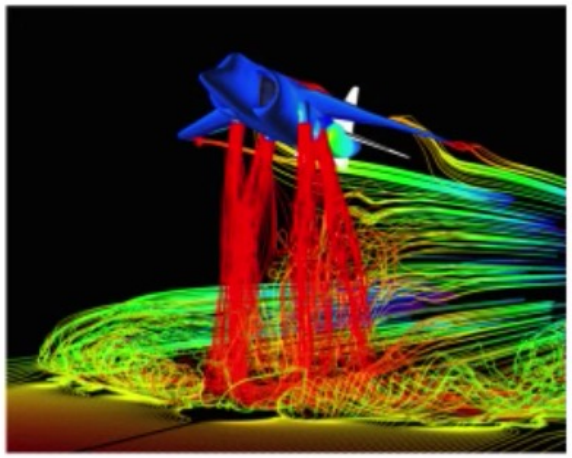
Vector Field Visualization

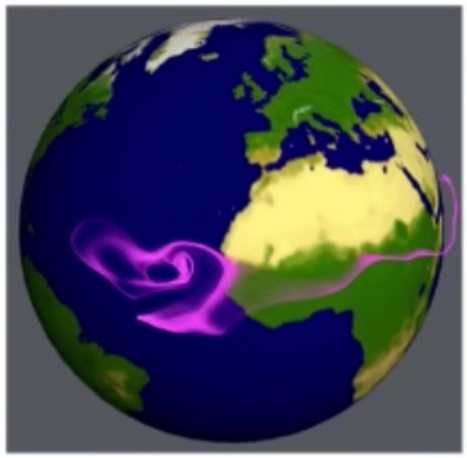
Overview

Courtesy of Prof. Han-Wei Shen
(CSE 5544, The Ohio State University)

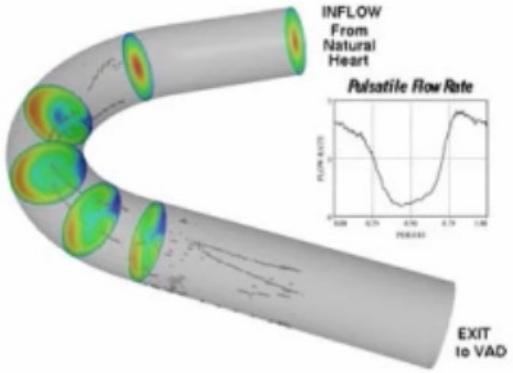
Vector Visualization Application



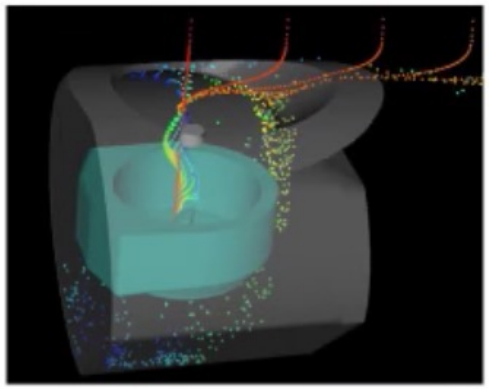
Computational Fluid Dynamics



Climate Modeling



Medical Applications

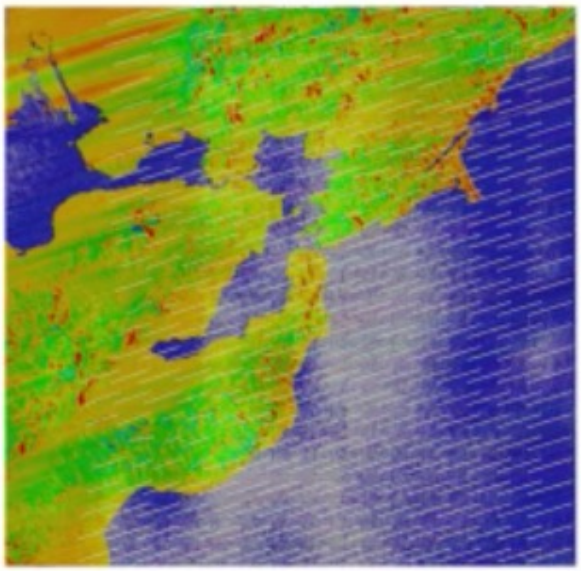


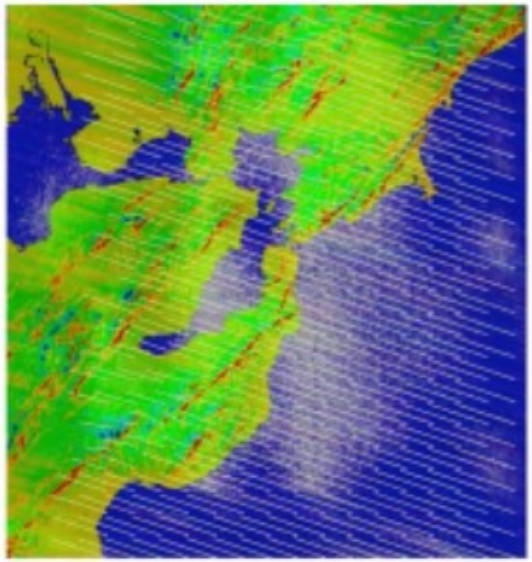
Astronomy

Vector Visualization Visualization

- Vector field: F(u) = v
  - u: position in the domain
    (x,y) in 2D (x,y,z) in 3D
  - v: the vector (u,v) or (u,v,w) at u

- Vector are often defined at discrete point at attributes at different time step





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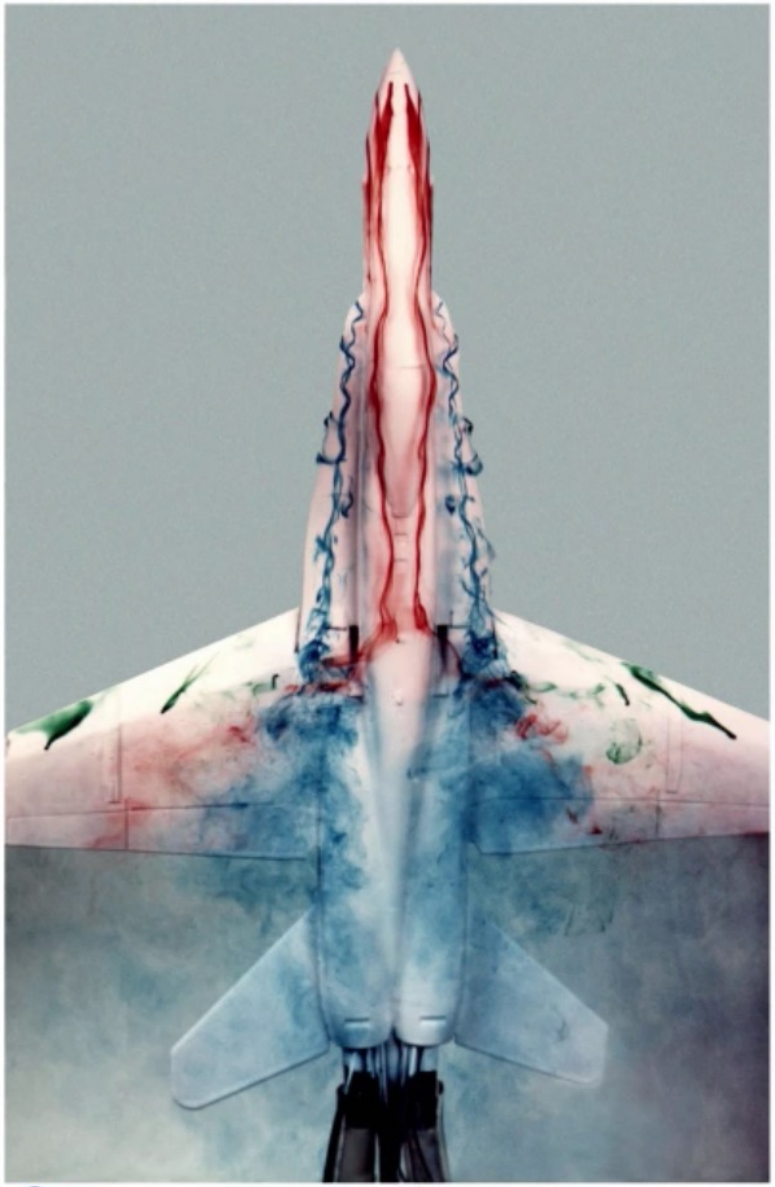
Methods for Experimental Flow Visualization - Adding Foreign Material

- Streakline: dye injected from a fixed position. By injecting the dye for a period of time, a line of dye in the fluid is visible
- Timeline: a row of small particles (hydrogen bubbles) release at right angle to flow. The motion of the particle show the fluid behavior
- Pathlines: small particles (magnesium powder in liquid; oil drops in gas) are added to the fluid. Velocity is measured by photographing the motion of the particles with a known exposure time

Experimental Flow Visualization



NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: ECN-33298-03 Date: 1985

1/48-scale model of an F-18 aircraft in Flow Visualization Facility (FVF)

Dryden Flight Research Center EC89-0096-240 Photographed 1989
F-18 HARV smoke and tuft flow visualization.
Angle of Attack = 30 deg. NASA photo.

Experimental Flow Visualization

Smoke and laser lighting sheet

(NASA Langley, FS-2001-04-64-LaRC)

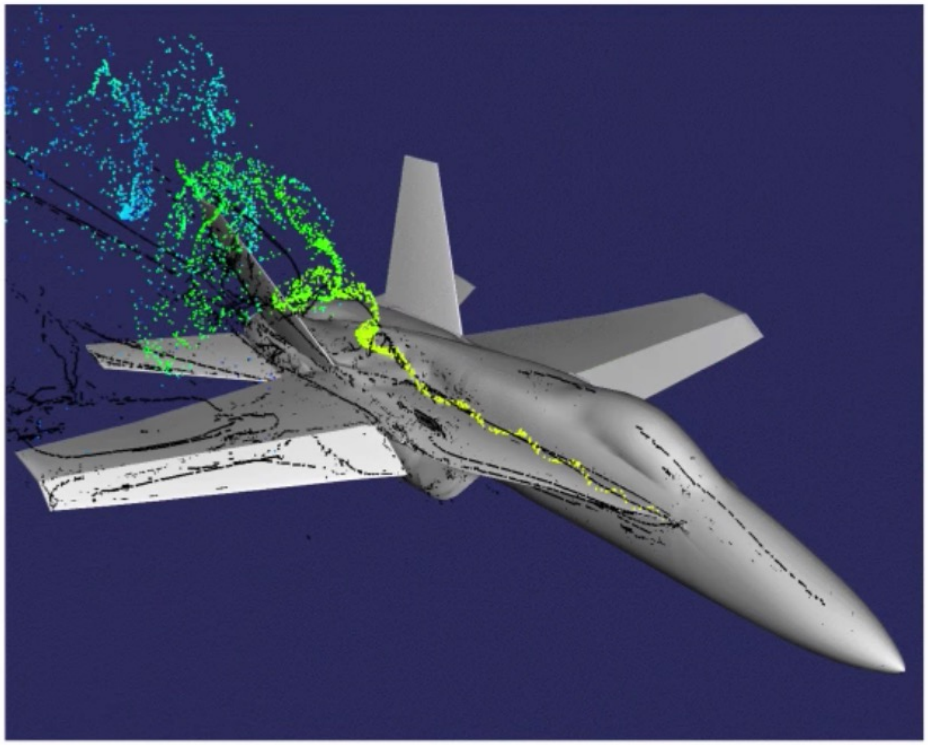
Oil flow visualization

(NASA Dryden, IS-97/08-DFRC-02)

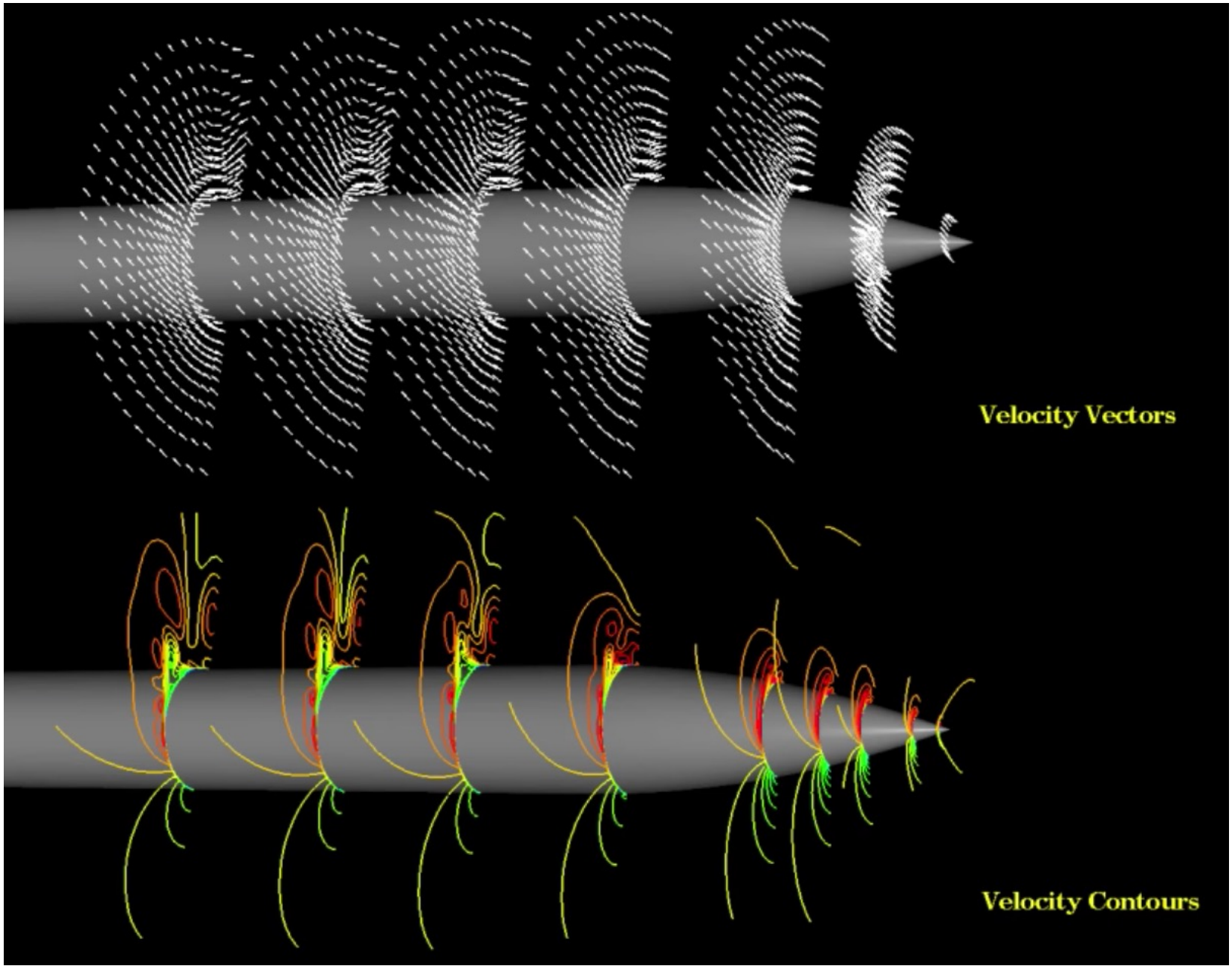
https://www.youtube.com/watch?v=-GMg536L4PU

Numerical Flow Visualization

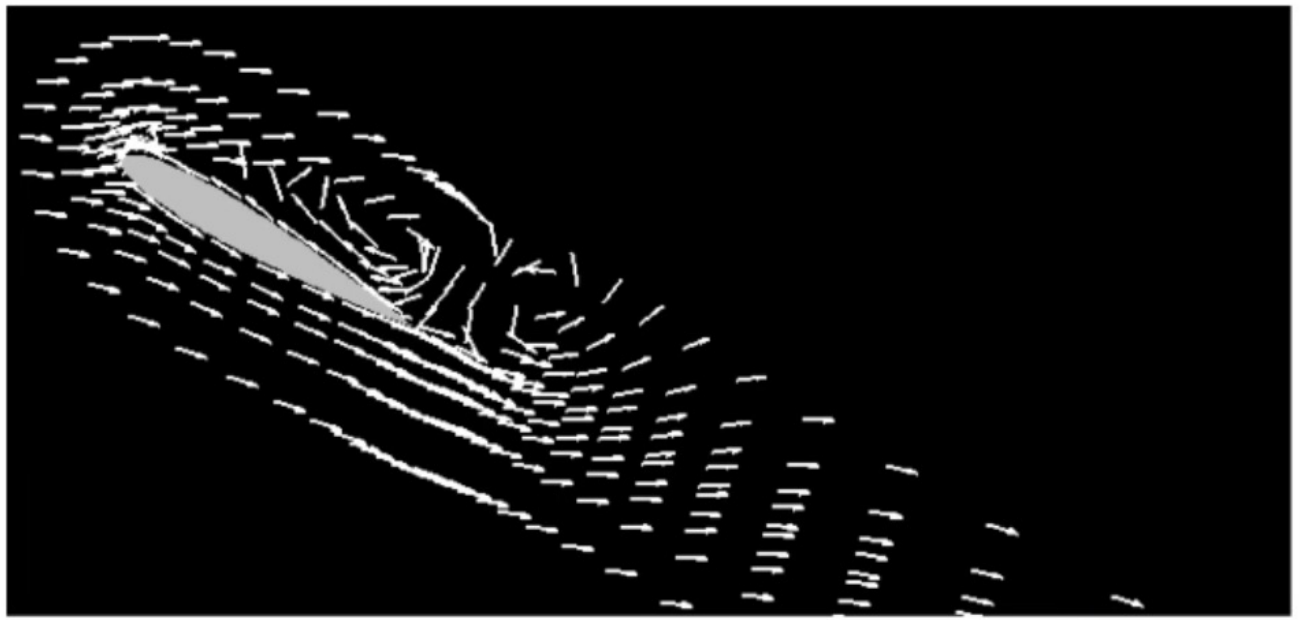
Though numerical flow visualization is not able to totally replicate the results from experimental flow visualization, it has been widely accepted as an effective mean to obtain accurate representation of the CFD flow solutions

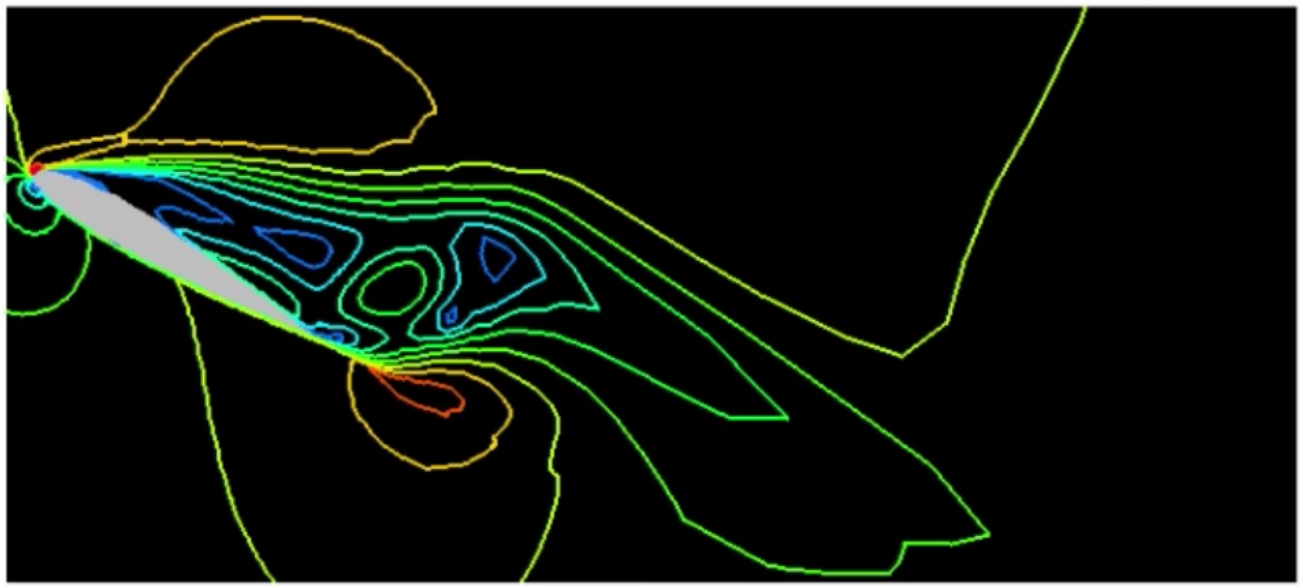


Numerical Flow Visualization – Basic Methods



Numerical Flow Visualization – Basic Methods





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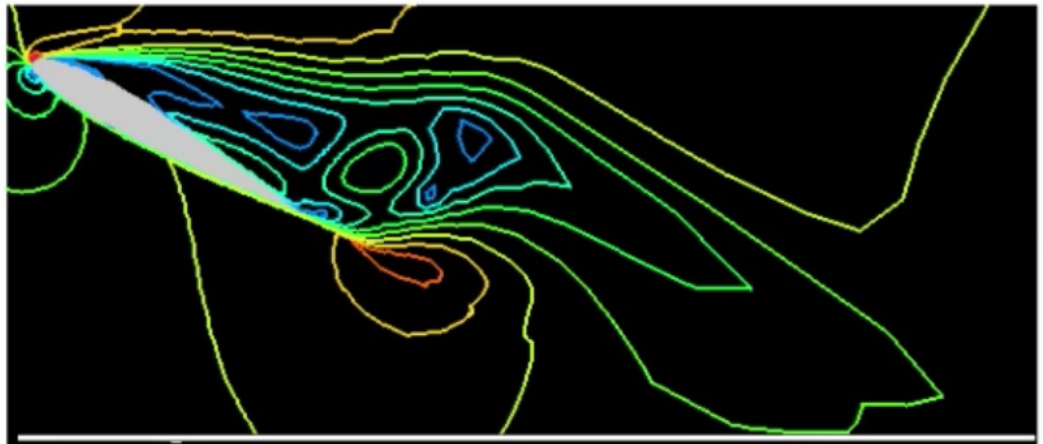
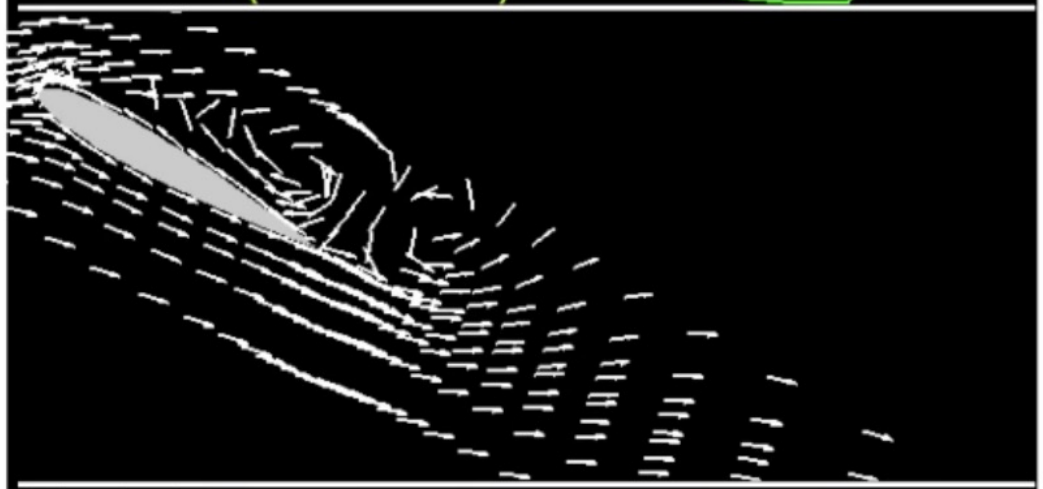
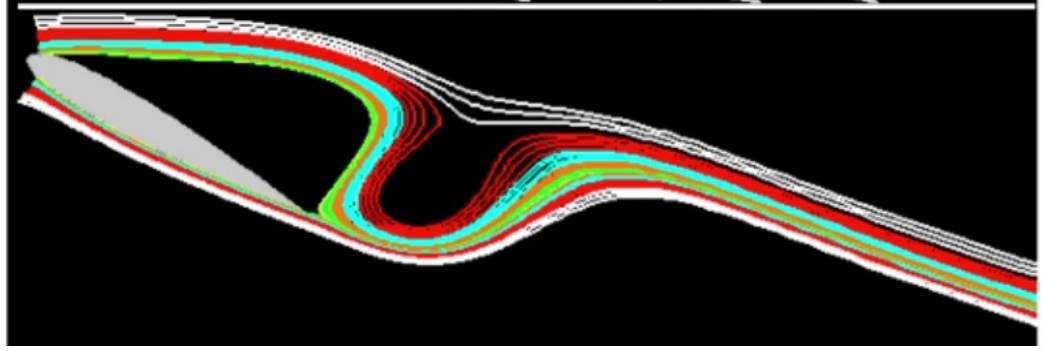


Velocity Magnitude Contours



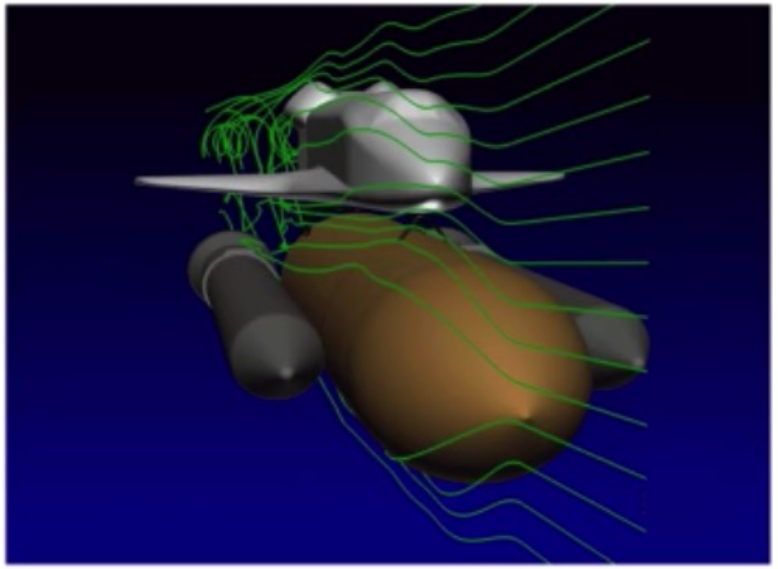
Vector Arrow Plots

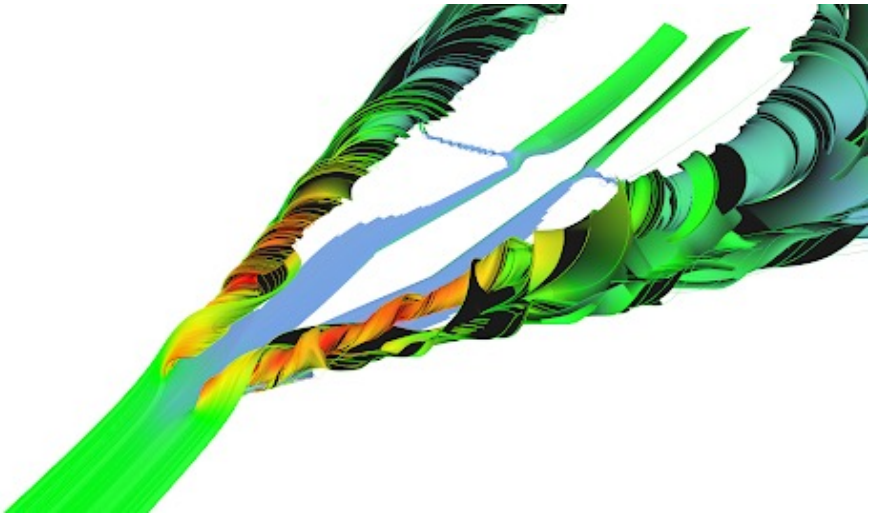


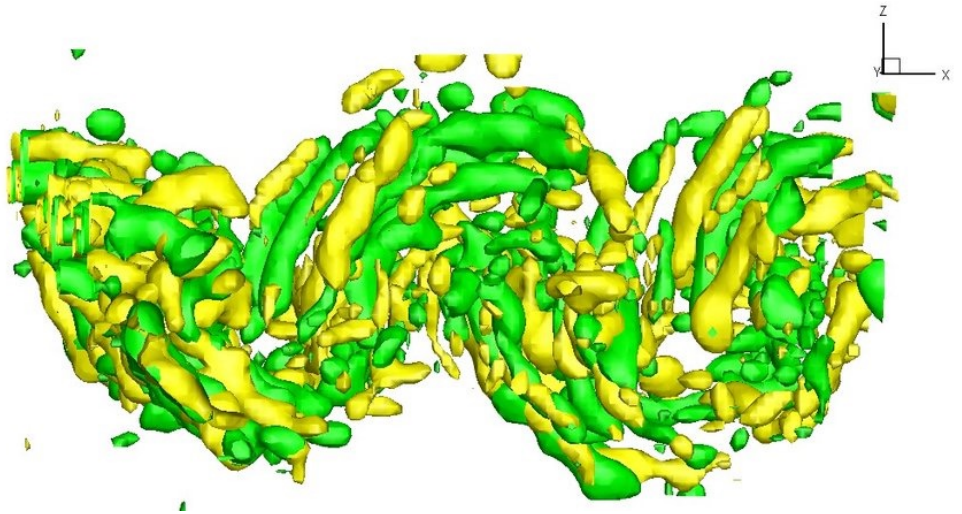
Particle Traces - Streamlines

Numerical Flow Visualization – Basic Methods

- Geometry-based methods: Render primitives from particle trajectories
  - 1D: streamlines, pathlines, streaklines
  - 2D: stream surface
  - 3D: flow volume

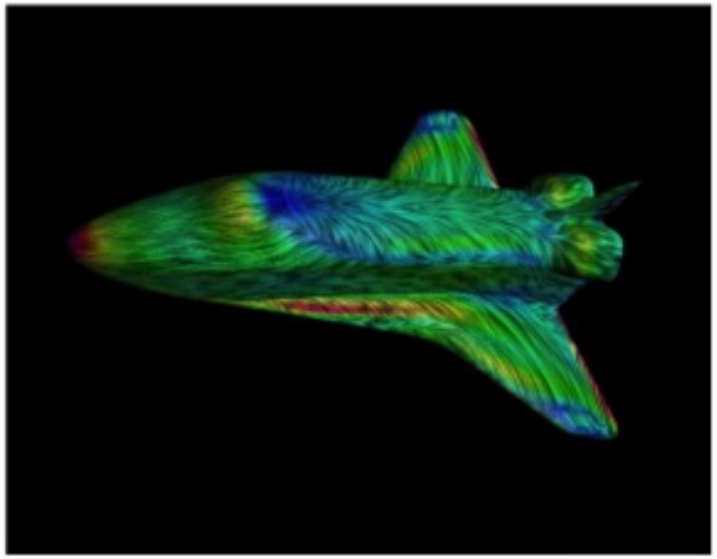


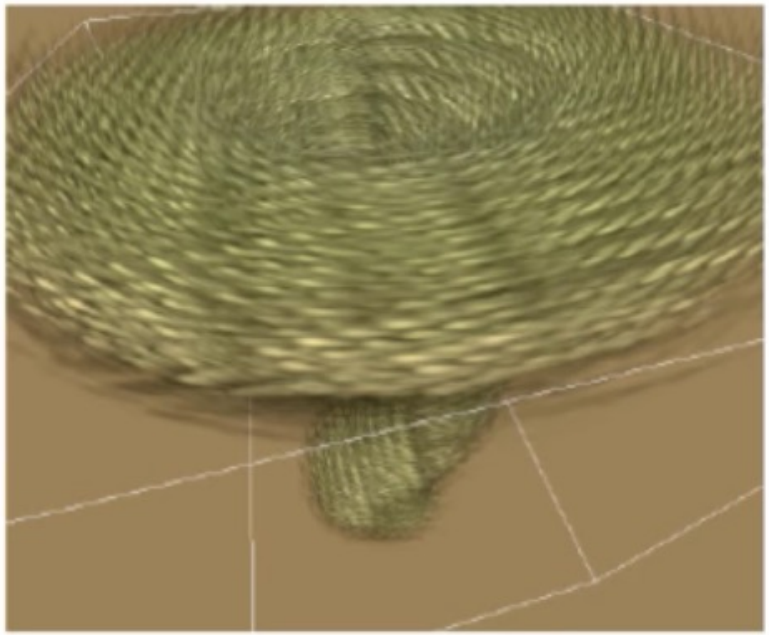




Numerical Flow Visualization – Basic Methods

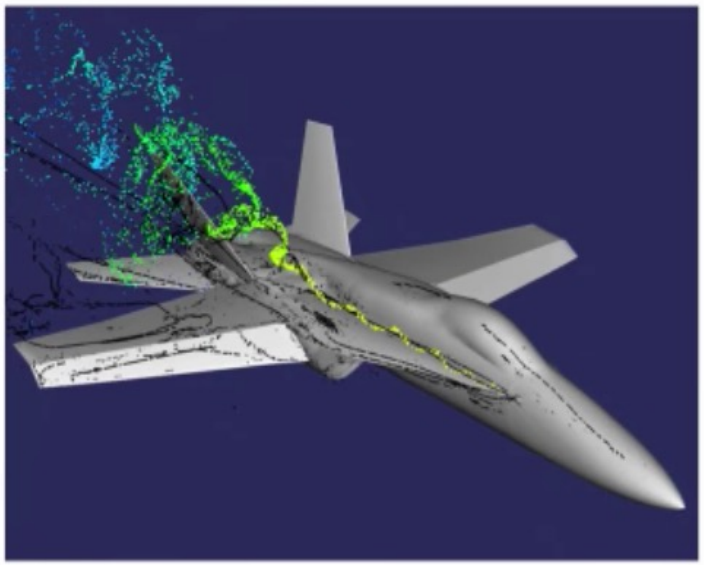
- Texture-based methods: create texture patterns following flow directions
  - Line Integral Convolution
  - Texture splates

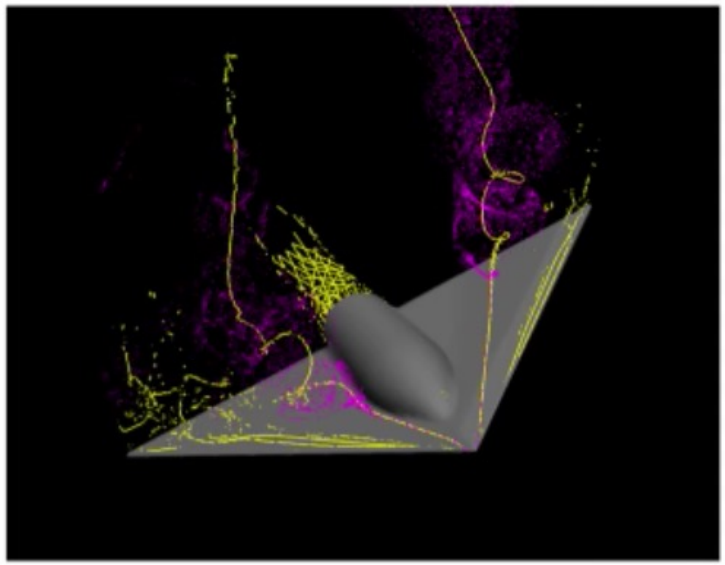




Numerical Flow Visualization – Basic Methods

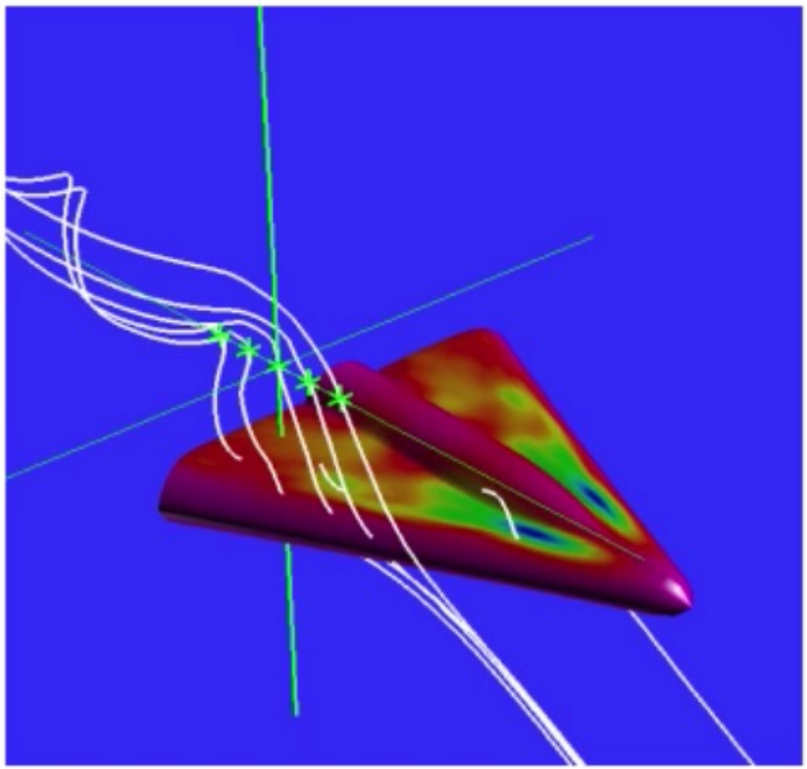
- Topological-based methods: Extract feature based on flow topology
  - Critical points
  - Vortex cores
  - Skin-friction lines

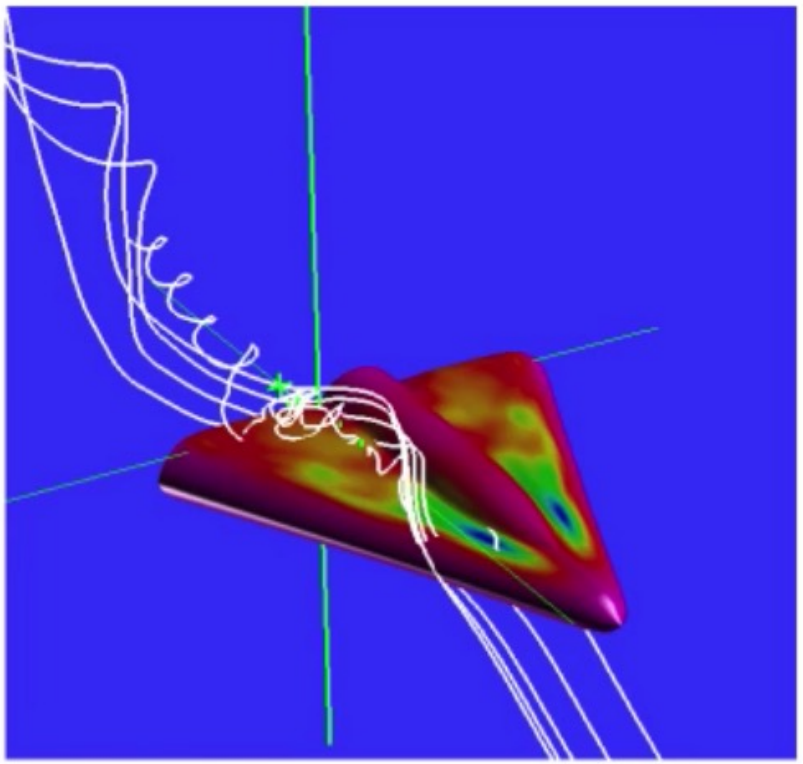




Particle Tracing

- Visualizing the flow directions by releasing particles and calculating a series of particle positions based on the vector field





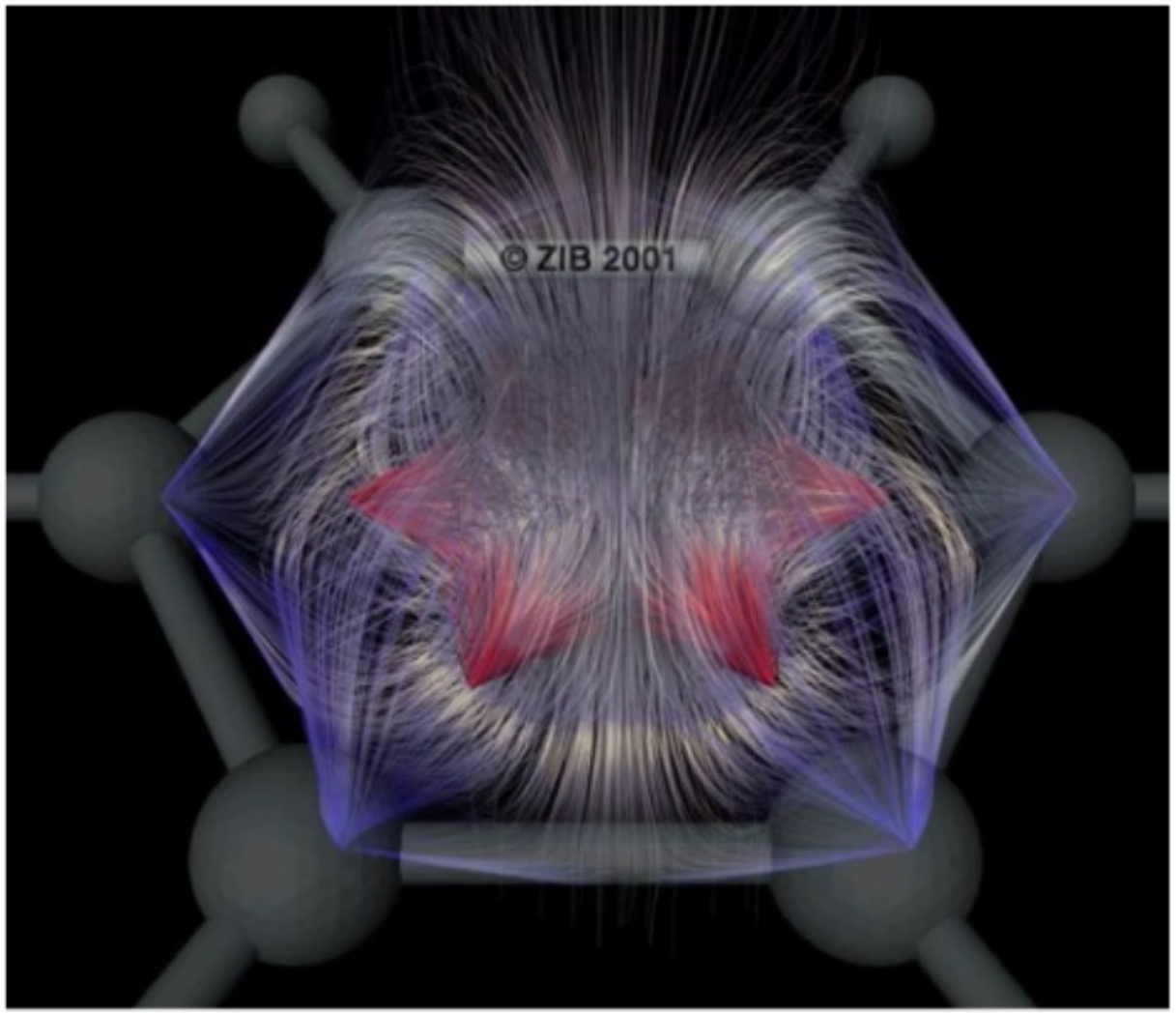
S09-02

Particle Tracing Challenge

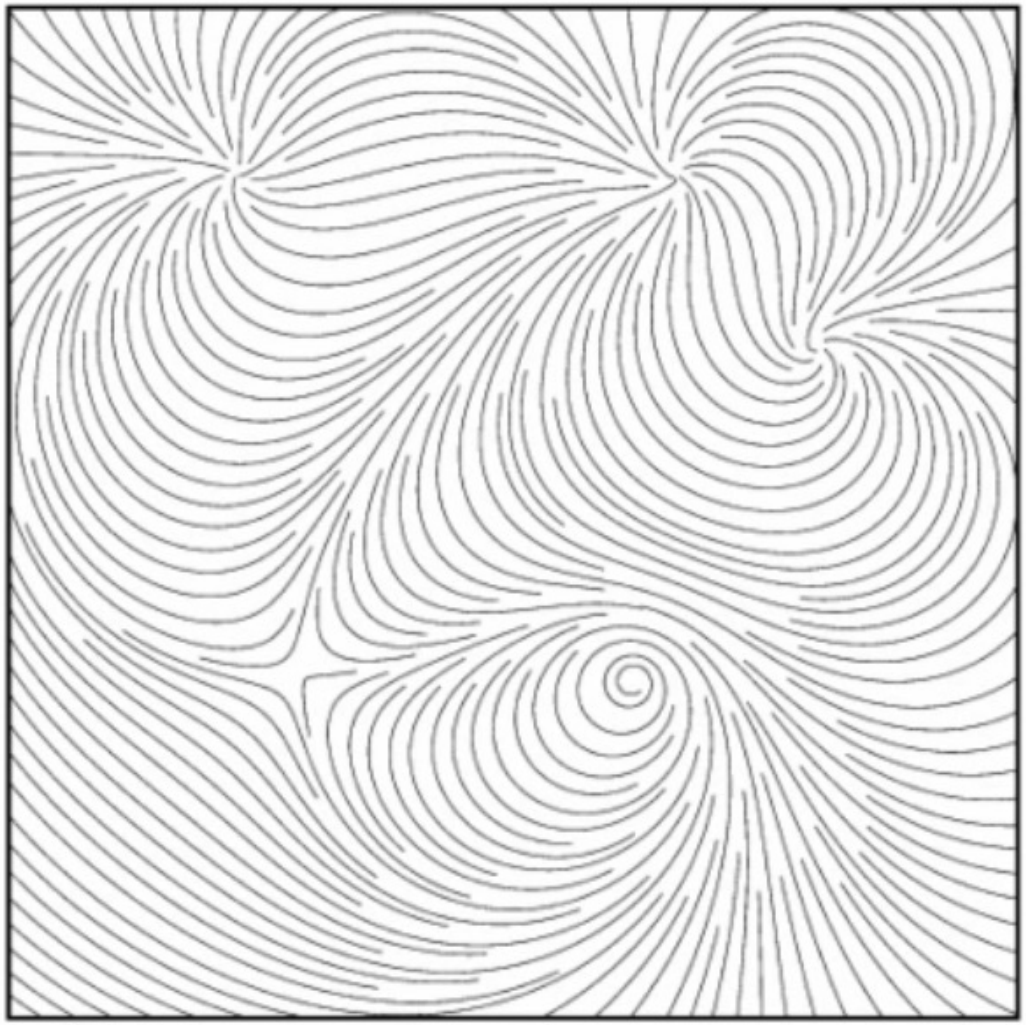
- Displaying streamlines is a local technique because you can only visualize the flow directions initiated from one or a few particles
- You need to know where to drop the particle seeds
- When the number of streamline is increased, the scene become cluttered
- Streamline computation is not cheap
- It is much more difficult to predict the data access pattern

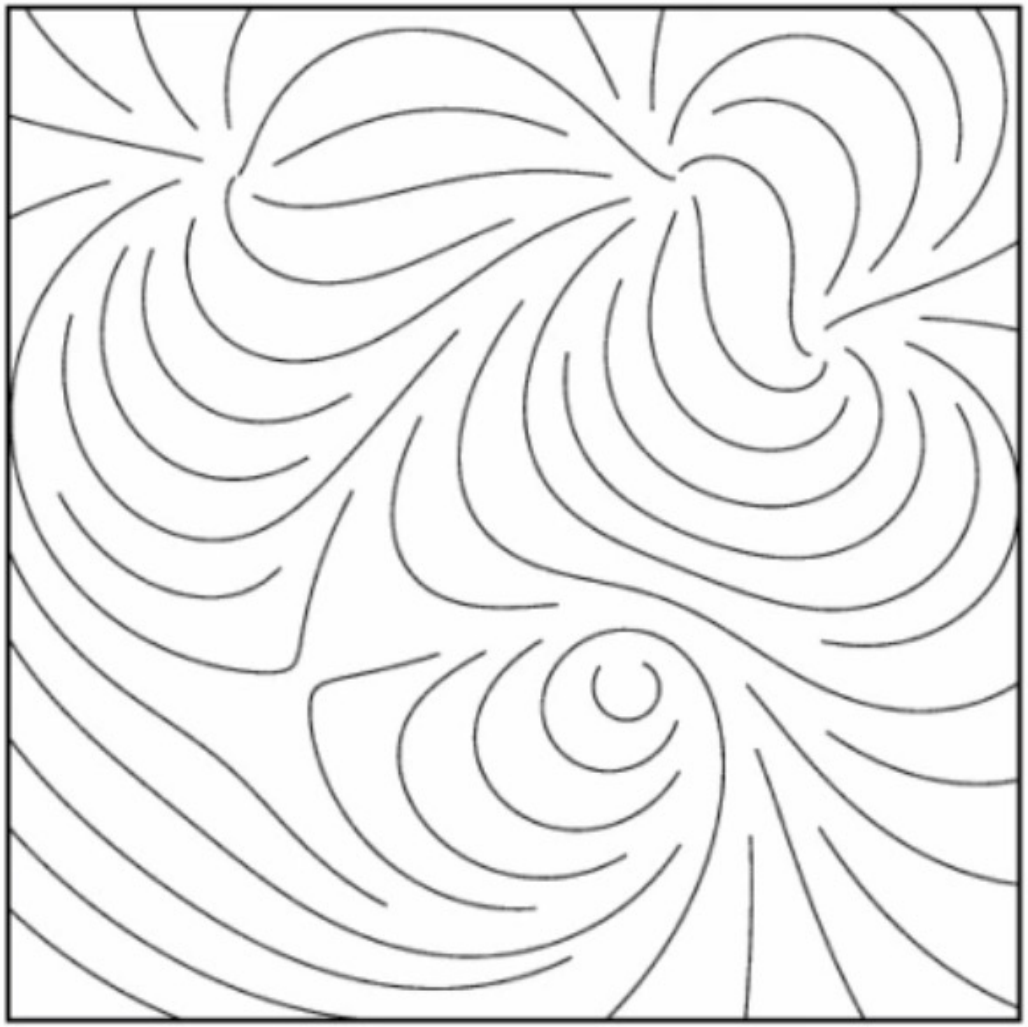
Particle Tracing Tracing

- Illumination certainly helps



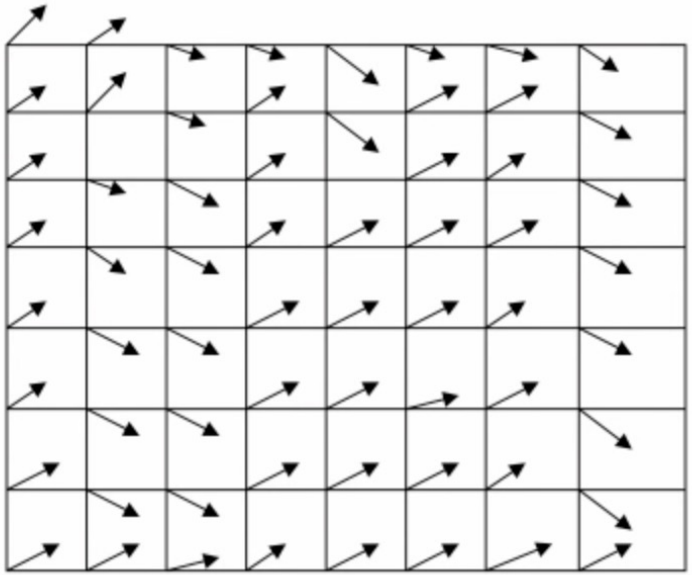
Seed Placement





Vector Glyphs

- Display the entire flow field in a single picture
- Minimal user intervention
- Example: Hedgehogs (global arrow plots)



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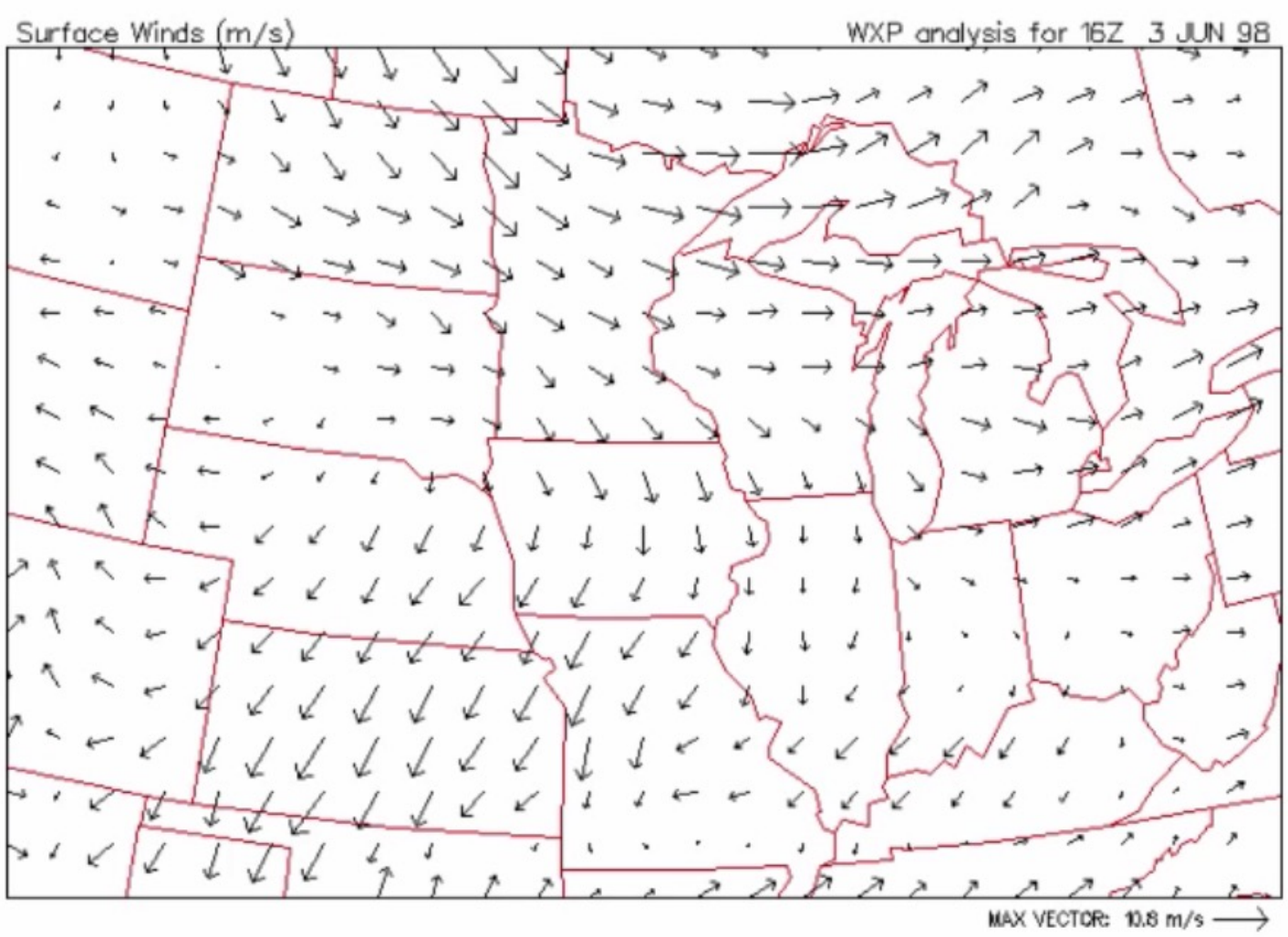

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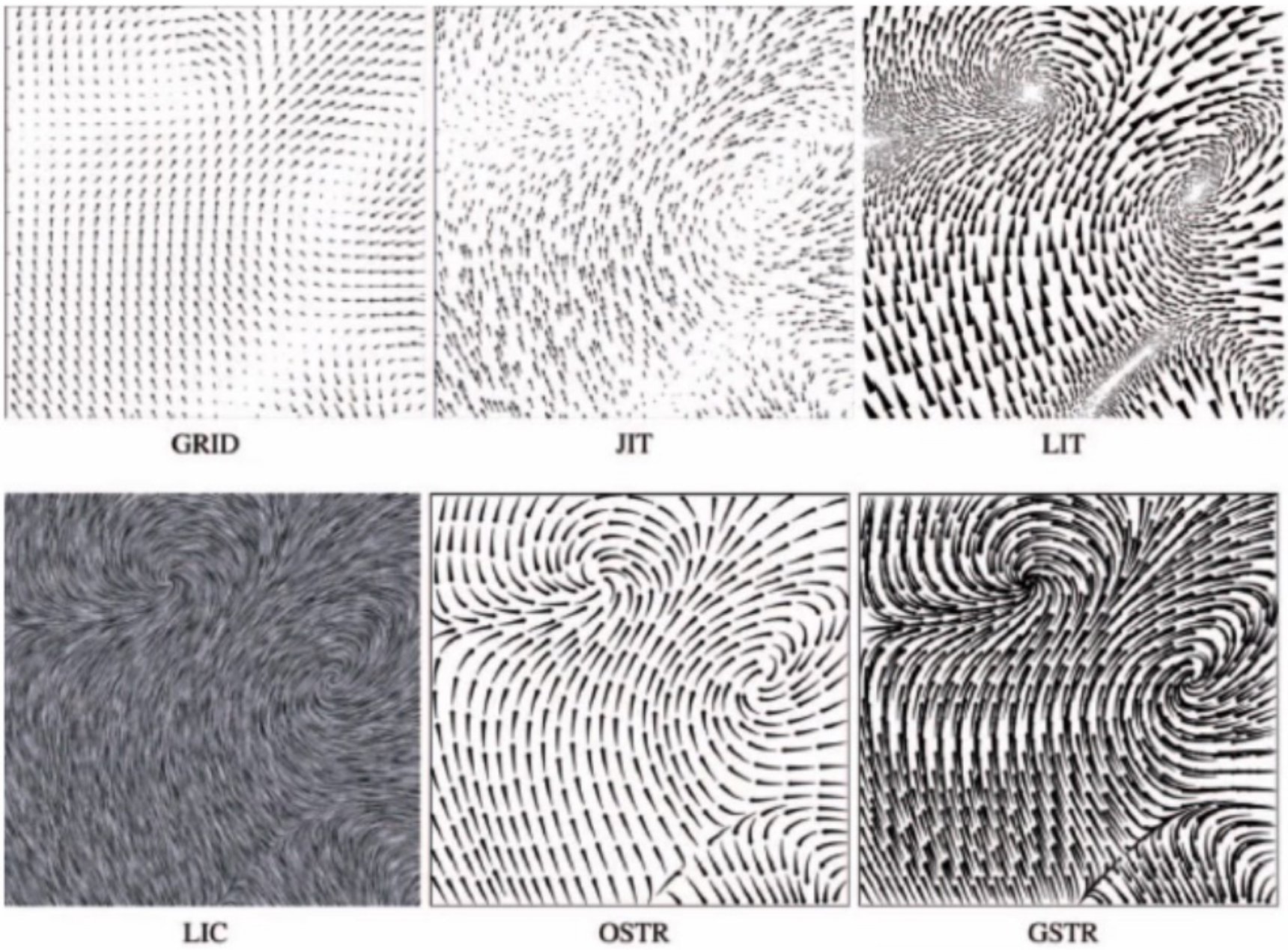
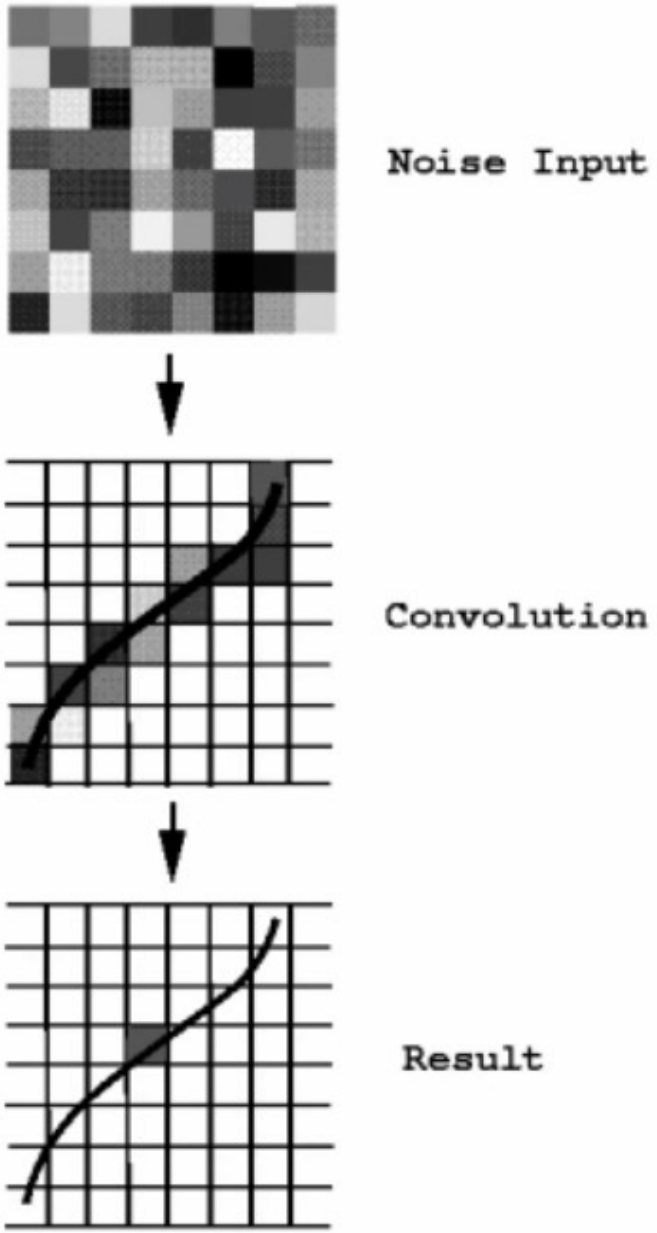
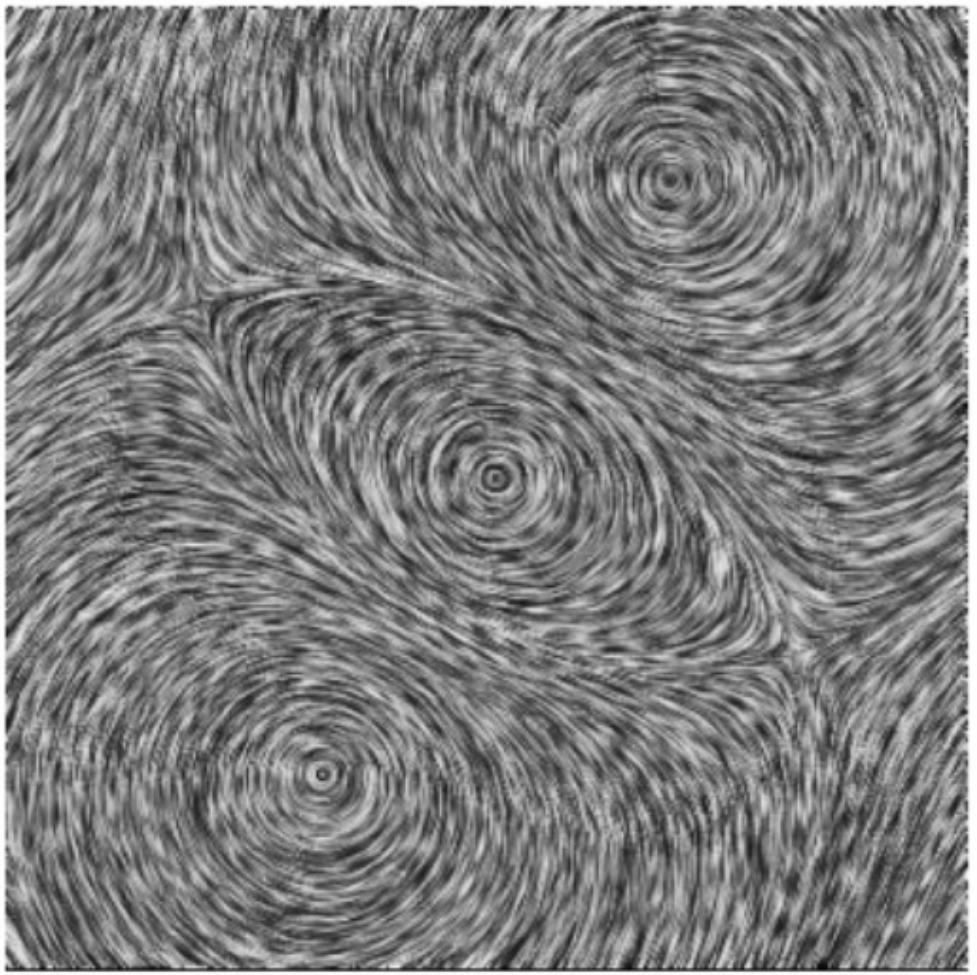
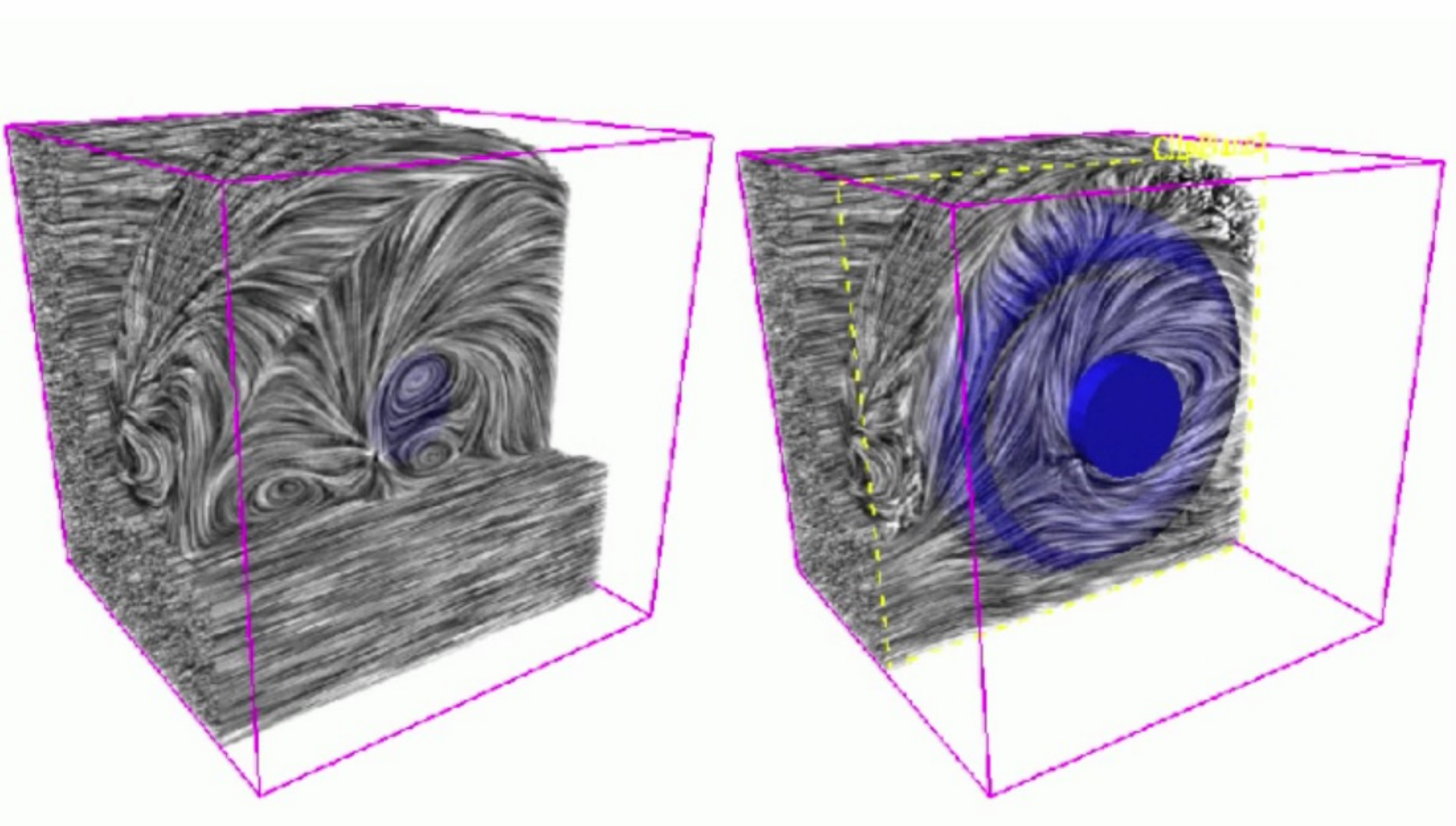


Line Integral Convolution (LIC)

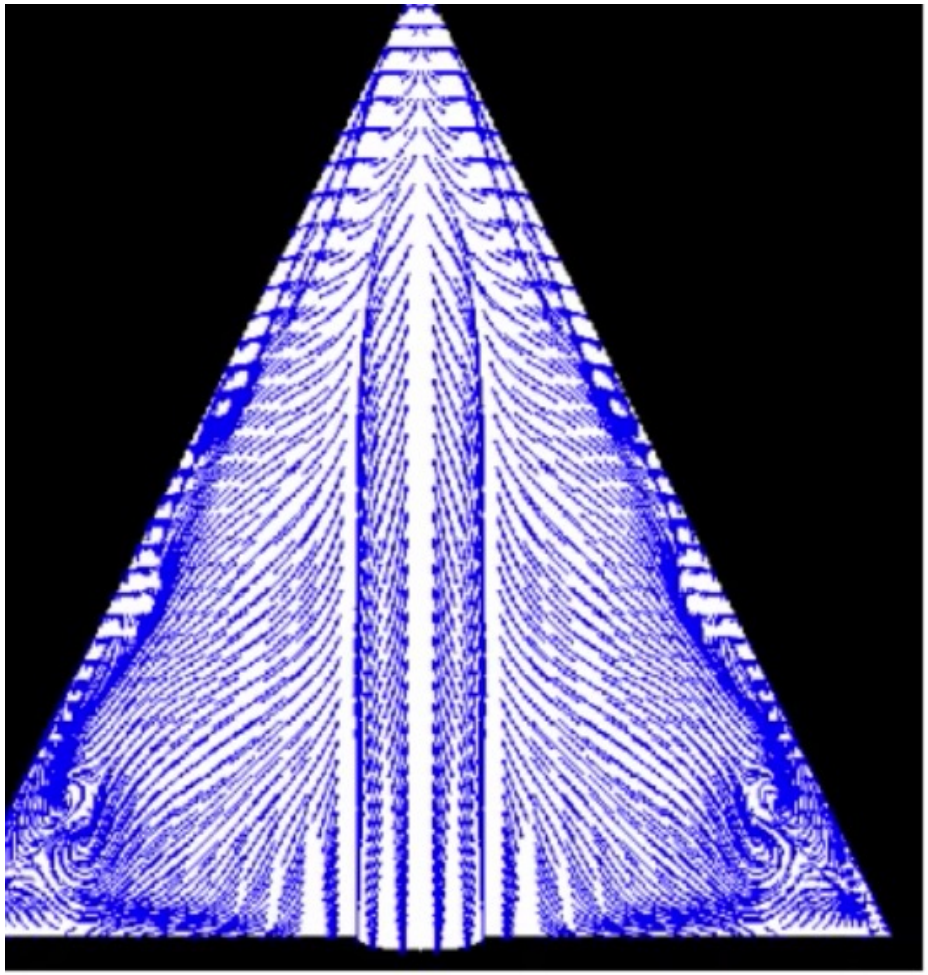


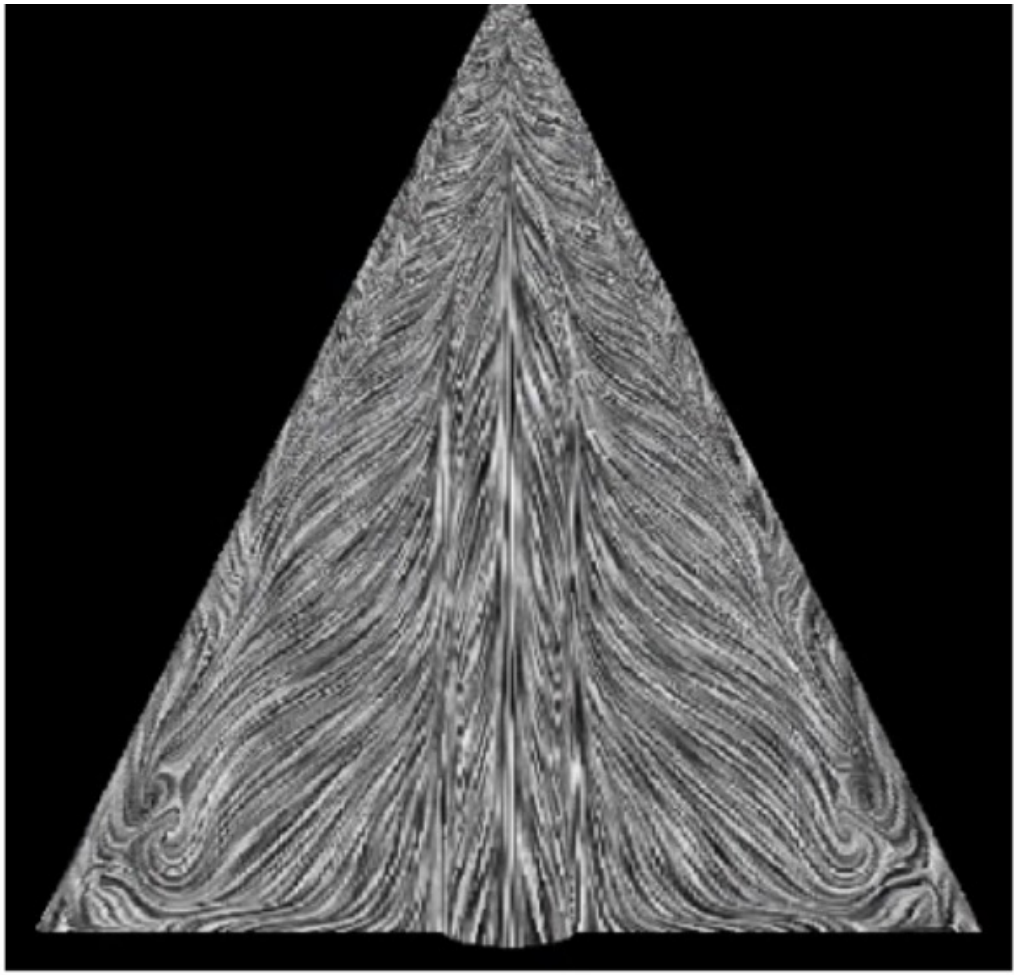


3D LIC



Comparison (Streamlines and LIC)





Animation Helps!

- https://www.windy.com/