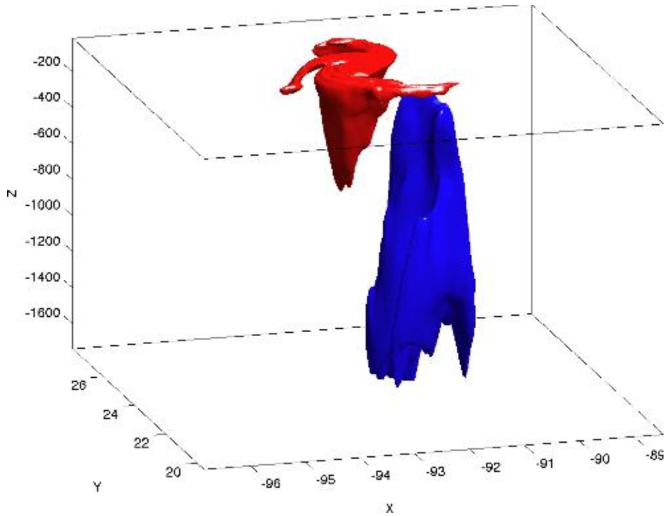
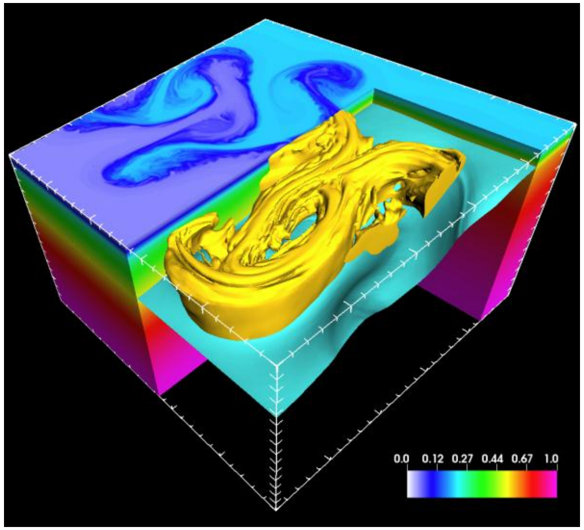
Computing LCS in 3D Vortex Dipole Structures

Ocean Models:

HYCOM: 1/100 Degree Gulf of Mexico
- Ubiquitous Anticyclone/Cyclone pairs
- Visualize via 3D advection diffusion solver



NEK 500: LES Meso-SubMeso Scale Instabilities
- SMS trigger transport by mesoscale dipole pairs
- Visualize via 3D (fixed time) FTLE

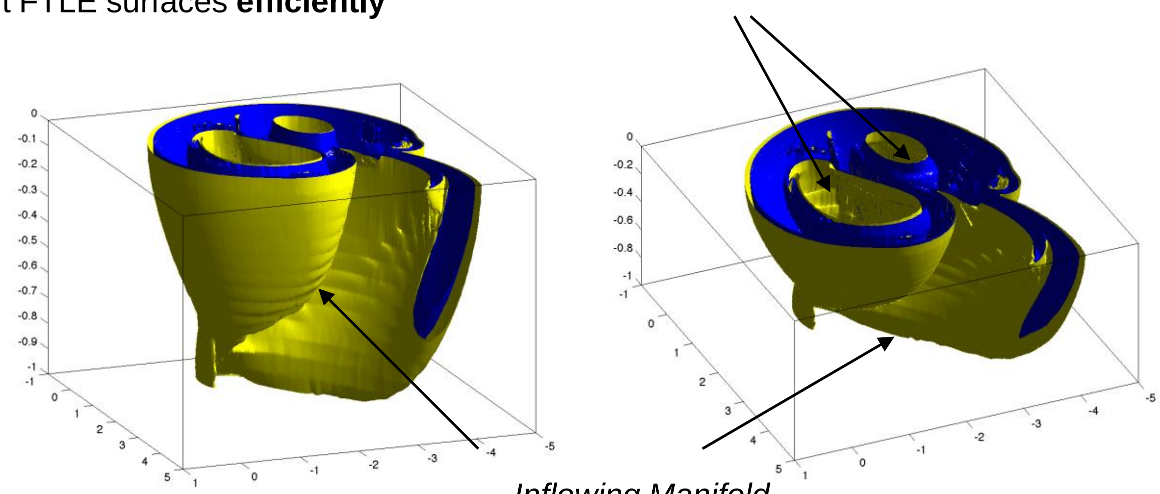


3D QG Model:

- 2D+1: No vertical velocity
- Contour advection/surgery (vorticity conserved)
- Chaotic advection outside closed vortex lines
- Goal: Construct time-dependent FTLE surfaces **efficiently**

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Invariant Cores



Inflowing Manifold sheet

Iterative Refinement Algorithm

Garthe, IEEE Visualization, 2007

LCS identification is Computationally Expensive:

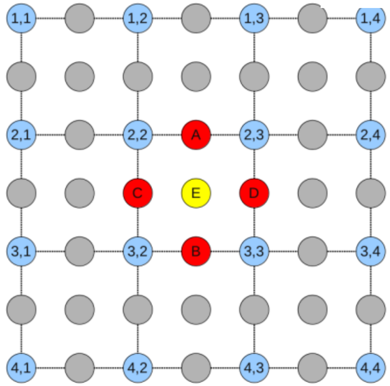
- Complex 3D structure (even in 2D+1 field)
- Need to resolve Lagrangian derivatives wrt initial conditions
- Fine initial particle grids: O(10^6) trajectories
- Time dependence (rerun at fixed times)
- Goal: Construct time-dependent FTLE surfaces **efficiently**

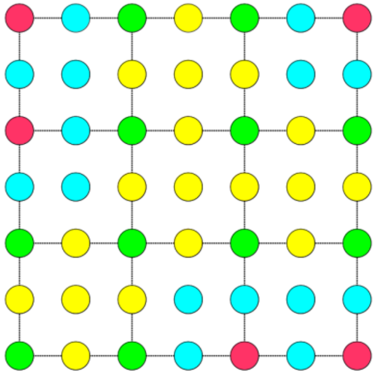
Iterative refinement scheme:

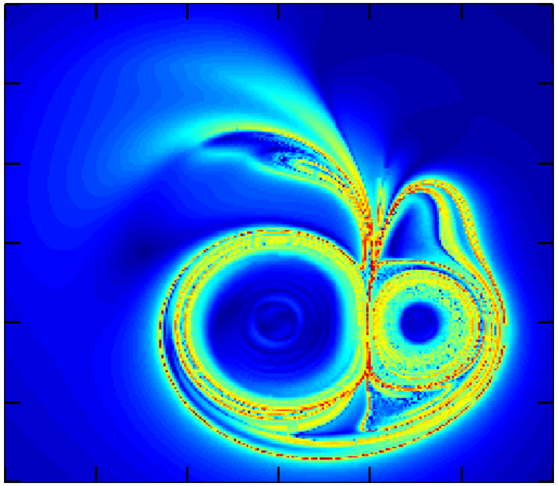
- Initialize FTLE on coarse and twice-fine ic grid
- Interpolate coarse FTLE onto fine grid and compare
- If comparison within tolerance, continue to interpolate - no need for further computations in this region
- Iterate to finer ic meshes

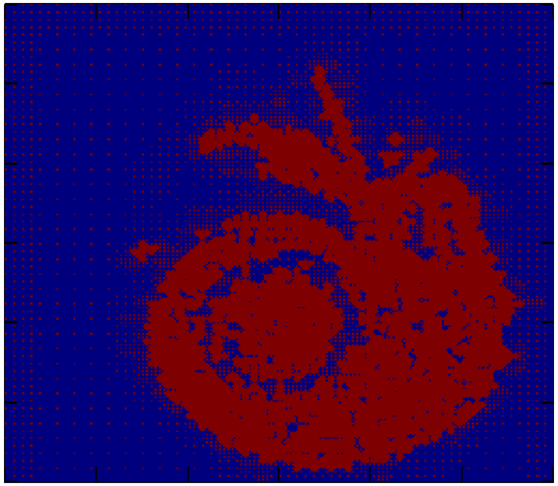
$$\lambda_A = \frac{1}{16}\left[9*\lambda_{(2,2)} + 9*\lambda_{(2,3)} - \lambda_{(2,1)} - \lambda_{(2,4)}\right]$$

$$\lambda_E = \frac{1}{4}\left[\lambda_A + \lambda_B + \lambda_C + \lambda_D\right]$$









Red Dots: Estimation was not accepted

Green Dots: Estimation was accepted

Blue Dots: New Calculated values

Yellow Dots: New Estimated values

Calculation of the FTLE field on top layer

Top: FTLE field

Bottom: Calculations vs Estimations

Image shows that only 35% of the FTLE field was actually calculated.