Leaving Flatland: 3D Aspects of Lagrangian Coherent Structures In Oceanic Flows

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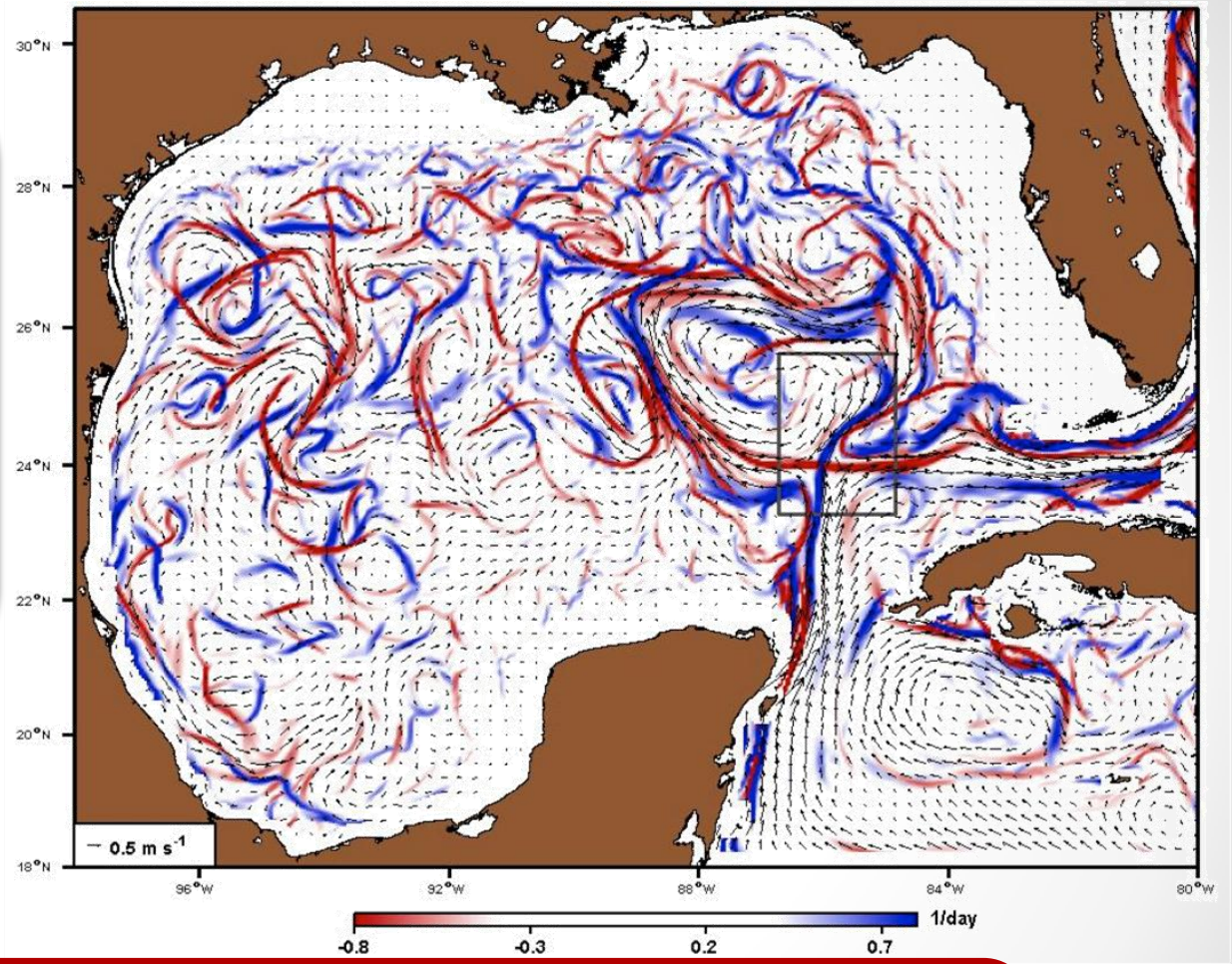
BACKGROUND

- Lagrangian Coherent Structures are time-varying 2D surfaces embedded in the 3D ocean.
- Most ocean models give 2D velocity fields along prescribed surfaces.
- Dynamical Systems methodologies, such as Finite Time Lyapunov Exponents, identify 1D mixing boundaries along model surfaces.

Flow Structures in the Gulf of Mexico

GoM – HYCOM
10 June 2010
10 m depth

Velocity snapshot and Finite Time Lyapunov Exponents (FTLE) from 3-day trajectories



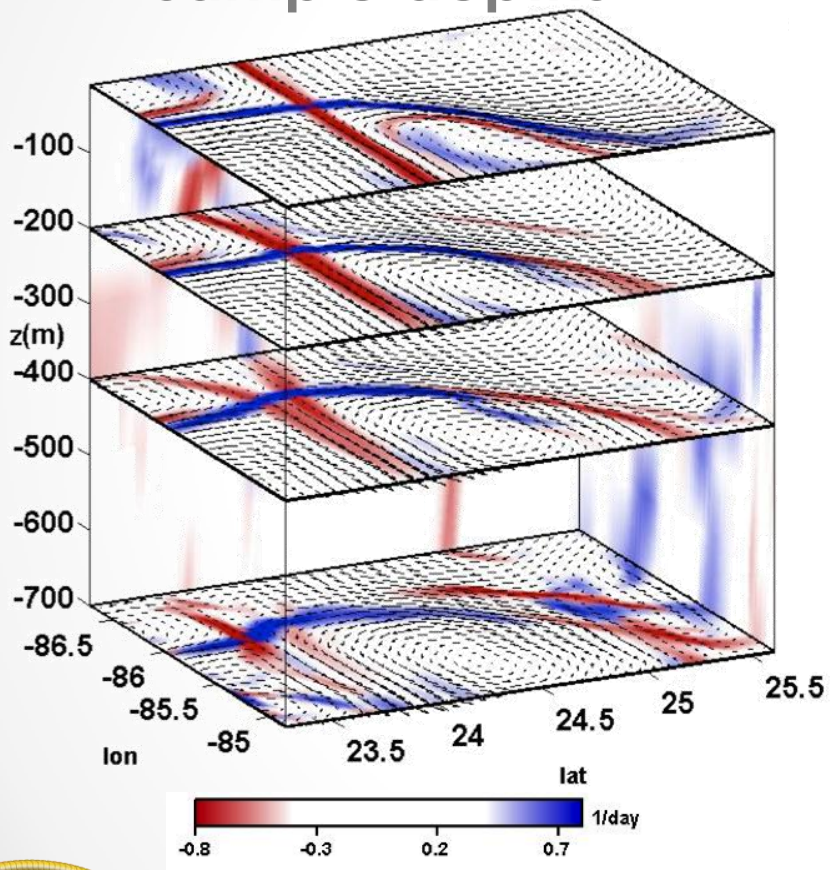
Model data thanks to NRL-Stennis.

Red and blue ridges indicate transport barriers.

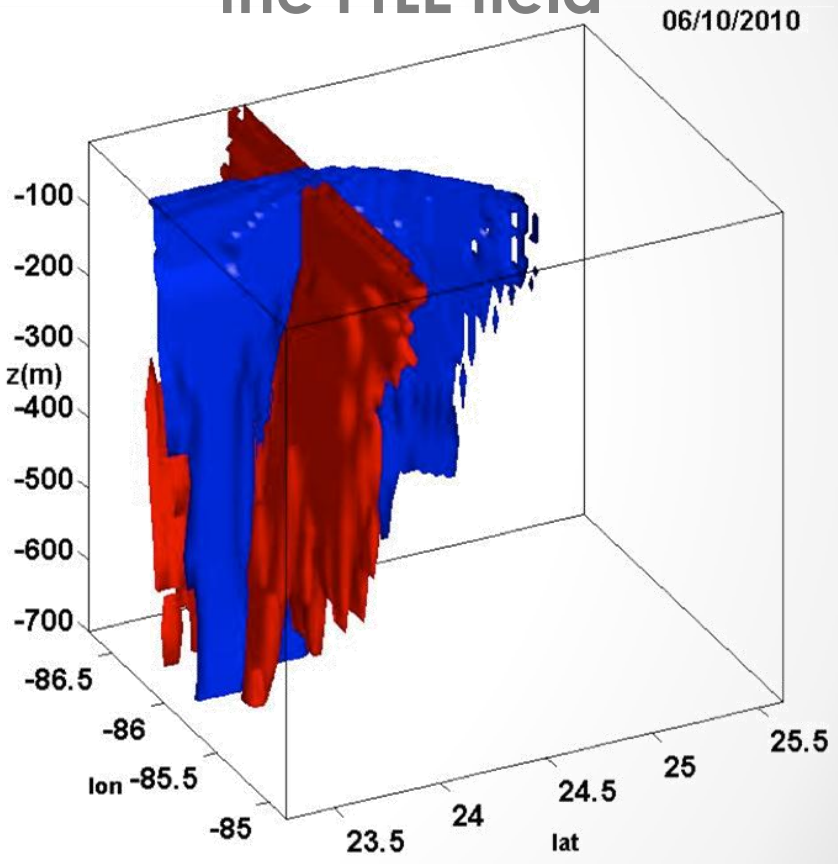
Red: Attracting
Blue: Repelling
Note intersection in box.

3D Views of the Hyperbolic Region

Currents & FTLEs at sample depths



Color bitmap of ridges in the FTLE field



Note the nearly vertical structure of the 2D surfaces demarcating transport barriers.

What have we learned?

- Two interrelated questions:
  - Are the 1D mixing boundaries correct representations of the intersections of the 2D LCS with these surfaces?
  - Can 2D velocities delineate 2D LCS?
- Applying the methodology to ABC-flow, the answer is **no**!
- From scale analysis, simplified GFD models, and preliminary applications to OGCMs we found that under typical conditions in the open ocean, the answer is a **qualified yes**.
- Example application to birth of mesoscale eddy.