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Geometry of unsteady flows SHAWN SHADDEN, Caltech, JOHN DABIRI, JERROLD MARSDEN — The ability to capture the dynamics of fluid flows continues to improve with advances in computational and empirical techniques. Interpretation of the data however is often quite heuristic. For steady flows, interpreting the flow structure is typically straightforward because streamlines and trajectories coincide. Therefore the Eulerian velocity field, or quantities derived from it, provide a clear description of the flow geometry. For unsteady flows, this is often not the case. A more natural choice is to understand the flow in terms of particle trajectories, i.e. the Lagrangian viewpoint. While the chaotic behavior of trajectories of unsteady systems makes direct interpretation difficult, more structured and frame-independent techniques have been developed. The method presented here uses finite-time Lyapunov exponent (FTLE) fields to locate Lagrangian Coherent Structures (LCS). The FTLE is a measure of divergence between fluid particle trajectories. LCS are maximizing curves (or surfaces in 3D) of FTLE fields, and can be thought of as distinguished material lines (surfaces) that separate regions of qualitatively different dynamics. We overview the theory and implementation of FTLE fields and LCS, and we apply this analysis to several distinct systems, including: vortex ring dynamics in laminar and turbulent flows, unsteady separation over an airfoil, and surface currents in the ocean.

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