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Quasi-Objective Coherent Structures from Single Lagrangian Trajectories

Nikolas Aksamit, Alex Encinas Bartos, and George Haller

Institute for Mechanical Systems, Swiss Federal Institute of Technology (ETH), Zürich, Switzerland (naksamit@ethz.ch)

Lagrangian coherent structures (LCS) provide a means to understand persistent flow features in an objective manner. There has been great success identifying and harnessing hyperbolic, elliptic, and parabolic structures in both oceanic and atmospheric flows. These approaches (e.g. FTLE, PRA, LAVD) rely on well resolved velocity information for the computation of the gradient of the flow map or vorticity deviation. Thus, for sparse data, such as that available from ocean drifters or atmospheric balloons, the quality of these methods quickly deteriorates. On the other hand, all elementary features of individual particle paths, such as velocity, acceleration, looping number, curvature and trajectory length, are non-objective, i.e., depend on the observer. To bridge this gap between LCS and sparse data, we derive measures of local material stretching and rotation that are computable from individual trajectories without reliance on other trajectories or on an underlying velocity field. Both measures are quasi-objective: they approximate objective (i.e., observer-independent) coherence diagnostics in frames satisfying a certain condition. We illustrate with several examples how our quasi-objective coherence diagnostics highlight elliptic and hyperbolic LCS, even from very sparse unstructured trajectory data. This approach shows great potential for expanding the possibilities of LCS applications through its simplicity, performance with sparse data, and enhanced computational efficiency.