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Sanjeeva Balasuriya, Nicholas T. Ouellette, Irina I. Rypina

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Generalized Lagrangian Coherent Structures

Sanjeeva Balasuriya

School of Mathematical Sciences, University of Adelaide, Adelaide, SA 5005, Australia

Nicholas T. Ouellette

Department of Civil and Environmental Engineering, Stanford University, Stanford, CA 94305, USA

Irina I. Rypina

Department of Physical Oceanography, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA

Abstract

The notion of a Lagrangian Coherent Structure (LCS) is by now well established as a way to capture transient coherent transport dynamics in unsteady and aperiodic fluid flows that are known over finite time. We show that the concept of an LCS can be generalized to capture coherence in other quantities of interest that are transported by, but not fully locked to, the fluid. Such quantities include those with dynamic, biological, chemical, or thermodynamic relevance, such as temperature, pollutant concentration, vorticity, kinetic energy, plankton density, and so on. We provide a conceptual framework for identifying the Generalized Lagrangian Coherent Structures (GLCSs) associated with such evolving quantities. We show how LCSs can be seen as a special case within this framework, and provide an overarching discussion of various methods for identifying LCSs. The utility of this more general viewpoint is highlighted through a variety of examples. We also show that although LCSs approximate GLCSs in certain limiting situations under restrictive assumptions on how the velocity field affects the additional quantities of interest, LCSs are not in general sufficient to describe their coherent transport.

Keywords: Lagrangian coherent structures, fluid flow, flow barriers, ocean eddies, atmospheric vortices