Mixing and transport in chaotic flows analyzed with Lagrangian coherent structures

F. Huhn*, A. von Kameke, V. Pérez-Muñuzuri
Grupo de Física No Lineal, Facultade de Física, Universidade de Santiago de Compostela, 15782 Santiago de Compostela, A Coruña, España

Transport in time-dependent aperiodic velocity fields can be highly chaotic. The dynamical systems approach to fluid transport allows to find geometrical coherent structures in the flow that govern the transport[1,4]. They are related to the stable and unstable manifolds of hyperbolic regions in the flow and serve to separate different regions of the flow that contain dynamically different trajectories. These coherent structures can be extracted by analyzing the properties of fluid trajectories that are obtained by integrating the time-dependent velocity field. In particular, we compute spatial maps of the Finite-Time Lyapunov Exponents (FTLE) of trajectories to unveil the structures. We study these patterns, called Lagrangian Coherent Structures (LCS), in different two-dimensional chaotic flows in the ocean and in the laboratory. Velocity fields are obtained from satellite data, a hydrodynamic coastal model or direct measurements via Particle Image Velocimetry (PIV). In all cases the extracted LCS act as barriers to transport and determine the local mixing dynamics. We show how LCS influence the transport of continuous active tracers, e.g., plankton concentration in the ocean[2] or a chemical reaction in the laboratory. LCS also serve to understand the pathways of surface drifters in an estuary and give a footprint of the water exchange processes of the estuary with the shelf[3].

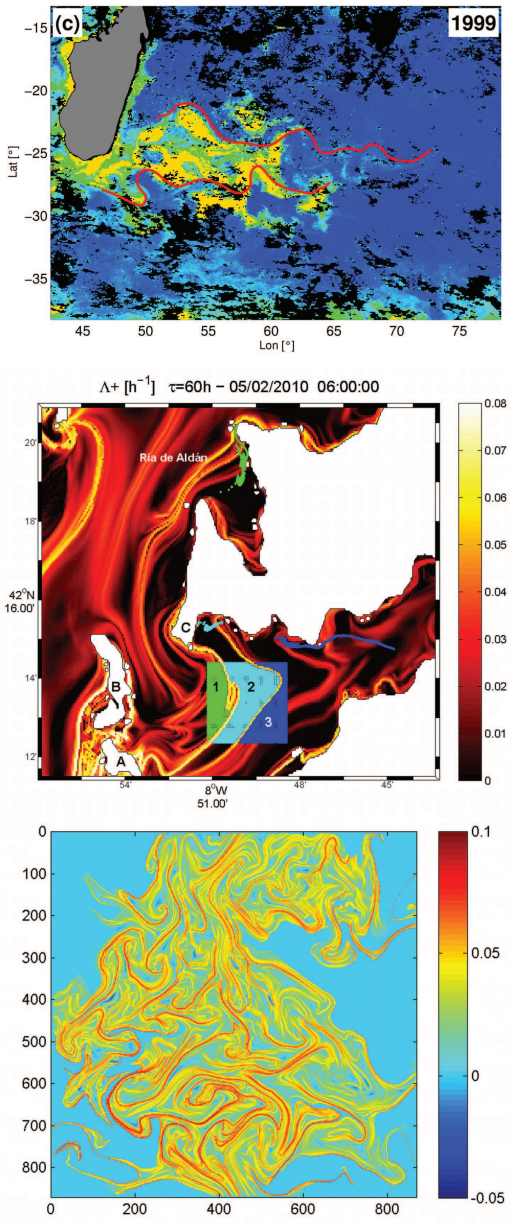

FIG. 1. Lagrangian Coherent Structures (LCS) from finite–time Lyapunov exponents (FTLE). (top) Madagascar plankton bloom between zonal jets. (middle) Virtual tracers in a tidal surface flow in the estuary Ria de Vigo. (bottom) Turbulent two-dimensional laboratory flow.

* florian.huhn@usc.es

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