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LAGRANGIAN ANALYSIS OF BACKWARD FACING STEP FROM EXPERIMENTS AND SIMULATIONS

María Inés Auliel [a,b], Gisela D. Charó [c,d], Denisse Sciamarella [c,d], Juan D'Adamo [a,b], Guillermo Artana [a,b]

[a] Laboratory of Fluid Dynamics (LFD)-Department of Mechanical Engineering-University of Buenos Aires-Av Paseo Colón 850-CABA-Argentina
[b] CNRS – CONICET – UBA. Institut Franco-Argentin d'Études de Dynamique des Fluides pour l'Environnement (IRL 2027 IFADyFE), University of Buenos Aires-Av Paseo Colón 850-CABA-Argentina
[c] CONICET – Universidad de Buenos Aires. Centro de Investigaciones del Mar y la Atmósfera (CIMA), C1428EGA Ciudad Autónoma de Buenos Aires, Argentina.
[d] CNRS – IRD – CONICET – UBA. Institut Franco-Argentin d'Études sur le Climat et ses Impacts (IRL 3351 IFAECI), C1428EGA Ciudad Autónoma de Buenos Aires, Argentina.

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Abstract. This work explores the generation of non-mixing islands in fluid flows—regions where particles remain grouped and resist mixing with the surrounding chaotic motion. Understanding such structures is essential in industrial mixing processes and in geophysical contexts, such as the dispersion of contaminants or nutrients in oceans. Traditional visualization using instantaneous Eulerian fields may misrepresent transport properties, motivating the use of Lagrangian Coherent Structures (LCS) to identify dynamically distinct regions. Building on principles of Chaos Topology [Gilmore & Lefranc, 2002; Sciamarella & Charó, 2024], we classify particles according to their dynamic traits to detect these regions from advection data, including both physical drifters and virtual particles in simulations. The method applied here extracts topological information from time series, following a delay embedding reconstruction of the dynamics and an approximation of the branched manifold underlying the attractor [Sciamarella & Mindlin, 2001]. This framework has been successfully applied to incompressible flow models such as the Driven Double Gyre, the Bickley Jet, and CFD simulations of cylinder wakes [Charó et al., 2020, 2021]. In this study, we analyze flow past a backward-facing step, using both 2D numerical simulations and wind tunnel experiments at matched Reynolds numbers. The region of interest is the downstream recirculating zone, influenced by the oscillatory dynamics of the reattachment point. Time series of particle positions are embedded to reconstruct phase-space dynamics, from which cell complexes are constructed. Topological coloring is used to label particles according to their finite-time dynamical class. The results distinguish regions of distinct Lagrangian behavior and allow for a comparison of the lifetime of non-mixing islands across experimental and numerical data, highlighting the robustness of the approach.

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