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Coherent Lagrangian vortices in three-dimensional unsteady flows

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Detecting barriers to, and facilitators of, transport is a fundamental problem in studying the behavior of Lagrangian trajectories in a fluid. A recent extension of two-dimensional results provides transport barriers in 3D flows as locally most attracting, repelling or shearing surfaces. This provides an objective definition of a Lagrangian vortex boundary as an outermost member of a family of most shearing cylindrical material surfaces. The detection of such a 3D vortex boundary yields an accurate estimate on the volume the vortex transports. We compute 3D Lagrangian vortices in kinematic models, and also use a global circulation model to extract sharp boundaries for coherent three-dimensional Agulhas rings in the South Atlantic.