Chaotic Advection in a Bounded 3-Dimensional Potential Flow

GUY METCALFE, CSIRO Materials Science & Engineering, LACHLAN SMITH, DANIEL LESTER, CSIRO Mathematics, Informatics & Statistics — 3-dimensional potential, or Darcy flows, are central to understanding and designing laminar transport in porous media; however, chaotic advection in 3-dimensional, volume-preserving flows is still not well understood.\footnote{Wiggins, J. Fluid Mech. \textbf{654} (2010).} We show results of advecting passive scalars in a transient 3-dimensional potential flow that consists of a steady dipole flow and periodic reorientation. Even for the most symmetric reorientation protocol, neither of the two invariants of the motion are conserved; however, one invariant is closely shadowed by a surface of revolution constructed from particle paths of the steady flow, creating in practice an adiabatic surface. A consequence is that chaotic regions cover 3-dimensional space, though tubular regular regions are still transport barriers. This appears to be a new mechanism generating 3-dimensional chaotic orbits. These results contrast with the experimental and theoretical results for chaotic Darcy flows.\footnote{Metcalfe et al, Phil. Trans. R. Soc. \textbf{A368} (2010a,b). \footnote{Lester et al, Phys. Rev. \textbf{E80} (2009), \textbf{E81} (2010).}}

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\bibitem{metcalfe2010} Metcalfe et al, Phil. Trans. R. Soc. \textbf{A368} (2010a,b).
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