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Lagrangian structures in time-periodic vortical flows

S. V. Kostrykin(1), A. A. Khapaev(2), V. M. Ponomarev(2), and I. G. Yakushkin(2)

(1) Institute of Numerical Mathematics, Russian Academy of Sciences, Moscow, Russia,
(2) Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences, Moscow, Russia

The Lagrangian trajectories of fluid particles are experimentally studied in an oscillating four-vortex velocity field. The oscillations occur due to a loss of stability of a steady flow and result in a regular reclosure of streamlines between the vortices of the same sign. The Eulerian velocity field is visualized by tracer displacements over a short time period. The obtained data on tracer motions during a number of oscillation periods show that the Lagrangian trajectories form quasi-regular structures. The destruction of these structures is determined by two characteristic time scales: the tracers are redistributed sufficiently fast between the vortices of the same sign and much more slowly transported into the vortices of opposite sign. The observed behavior of the Lagrangian trajectories is quantitatively reproduced in a new numerical experiment with two-dimensional model of the velocity field with a small number of spatial harmonics. A qualitative interpretation of phenomena observed on the basis of the theory of adiabatic chaos in the Hamiltonian systems is given.

The Lagrangian trajectories are numerically simulated under varying flow parameters. It is shown that the spatial-temporal characteristics of the Lagrangian structures depend on the properties of temporal change in the streamlines topology and on the adiabatic parameter corresponding to the flow. The condition for the occurrence of traps (the regions where the Lagrangian particles reside for a long time) is obtained.