Intermittency effects in turbulent transport: expectation of the scalar concentration

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Scalar transport by turbulent flows is best described in terms of Lagrangian parcel motions. We examine a simplified point vortex flow, measuring the Eulerian distance travel along Lagrangian trajectories to determine the probabilistic impulse response function in the absence of molecular diffusion. As expected, the mean squared Eulerian displacement scales ballistically for times shorter than the integral time and diffusively for longer times. However, the displacement distribution at any given time is only approximately that of a random walk with Gaussianly distributed step sizes. Significant deviations of the distribution from that of anomalous or normal diffusion are found. The probability of long distance transport is reduced at inertial time scales by spatial and temporal intermittency in the flow. This can be statistically mimicked by a series of trapping events with durations uniformly distributed between the Kolmogorov and integral time scales. The probability of long distance transport is enhanced beyond that of the random walk for times shorter than the Kolmogorov or longer than the integral time, likely because of the superposition of vortex contributions. These findings have implications for turbulent transport modeling beyond the simplified flow studied.

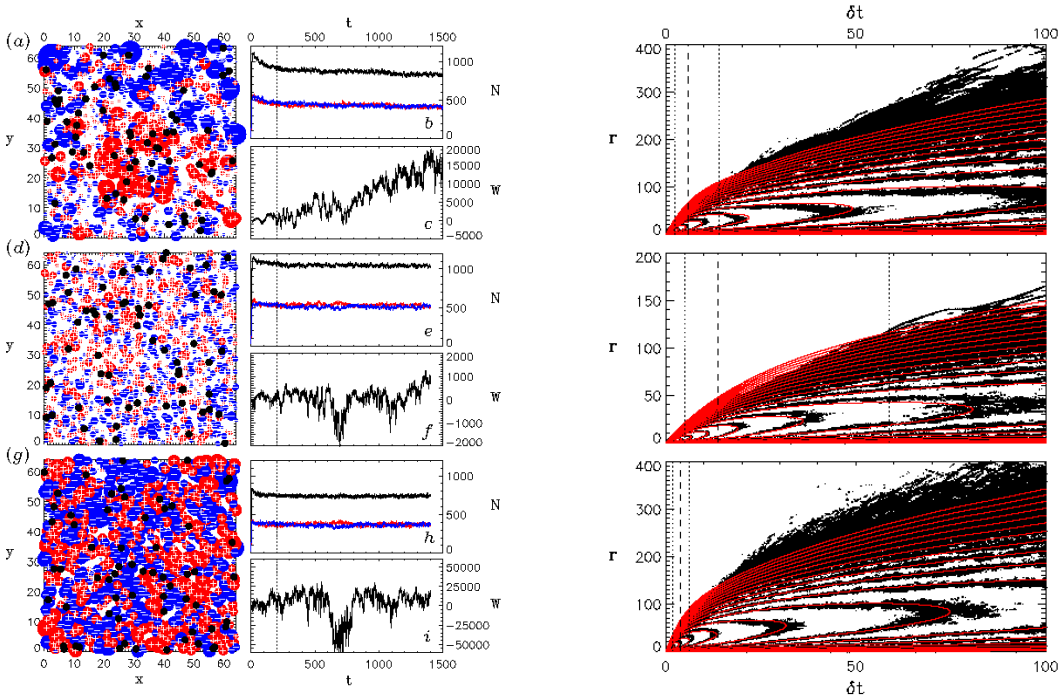

Figure 1: Snapshots of the point vortex field (*left*) in three simulations employing vorticity (*a*) and kinetic energy conserving, (*d*) and (*g*), merger schemes. Symbol size represents vortex amplitude, and black dots indicate the instantaneous position of passive Lagrangian tracers in the flow. Time series of the vortex interaction energy W indicate a prominent inverse cascade only when the vorticity conserving scheme is employed. Contours (*right*) of the logarithm of probability distribution of the Eulerian distance r traveled along Lagrangian trajectories in time δt are approximated by a random walk of variable steps size (*red* curves), but important deviations exist at both long and short times.