Numerical studies of encounter rates and transit times for small moving surfaces in turbulent flows

H. L. Pécseli and J. Trulsen

University of Oslo, Norway

The motion of passively advected particles is studied by numerical simulations of homogeneous and isotropic turbulent flows. Simultaneous trajectories of many (up to 400.000) passively moving point-particles are followed in time. Two problems are addressed: encounter rates and transit time distributions. Encounter rates are obtained by following small virtual surfaces with characteristic radii in the inertial as well as in the viscous range of the turbulence. For a Lagrangian description, we select one of these reference particles as the “center” of a self-consistently moving closed absorbing surface. The surface determines a reference volume, which may be a sphere, for instance. We subsequently obtain estimates for the time variation of the statistical average of the particle flux into this volume. The variation of the flux with the scale size of the surface of interception, as well as the variation with basic flow parameters, is well described by a simple model, in particular for radii smaller than a characteristic large length scale, the outer scale, for the turbulence. For very small radii the particle flux is given by Brownian motion. The length scale separating the turbulent fluxes for scales in the viscous subrange and Brownian fluxes is expressed in terms of the Schmidt number. We estimate also the probability distribution of the transit times of particles through the prescribed volume. The transit time is defined as the difference between entrance and exit times of surrounding particles advected through this volume by the turbulent motions. Simple scaling laws are obtained for the probability density of the transit times in terms of the basic properties of the turbulent flow and the geometry. The analysis is extended to include a finite reaction time, so that particles spending times shorter than some prescribed time-interval will not interact with the reference particle, but leave the reference volume, with the possibility of interacting at some later time. The reference volumes need not be spherical, also other shapes are considered. The numerical results are compared to similar observations from laboratory experiments, and good agreement has been demonstrated. The results of our analysis are relevant for describing some features of chemical reactions, but also for understanding details in the feeding rate of micro-organisms in turbulent waters, for instance.