The Eddy-Diffusivity in Turbulent Two-Particle Dispersion

DAMIEN BENVENISTE, Physics, Johns Hopkins University, GREGORY EYINK, Applied Mathematics, Johns Hopkins University — R. H. Kraichnan (1966) and T. S. Lundgren (1981) derived a formula for the eddy-diffusivity in Richardson’s theory of turbulent 2-particle dispersion:

\[ \eta_{ij}(r, t) = \int_0^t ds \langle (u_i(x + r, t) - u_i(x, t))(u_i(x + r, t|s) - u_j(x, t|s)) \rangle. \]

This formula involves the Lagrangian velocity field \( u(x, t|s) \) experienced at time \( s < t \) by the fluid particle which is at point \( x \) at time \( t \). Evaluating this formula requires tracking fluid particles backward in time, a difficult task with standard DNS. We compute the formula using the JHU Turbulence Database,\(^1\) which stores the entire spacetime history of a 1024\(^3\) DNS of homogeneous, isotropic turbulence at \( Re_\lambda = 433 \). We average over particle pairs started at many different initial positions \( x \) with initial separations \( r \). We obtain a time-dependent eddy-diffusivity \( \eta_{ij}(r, t) \) which has Batchelor scaling \( (\varepsilon r)^{2/3} t \) for short time and Richardson scaling \( \varepsilon^{1/3} r^{4/3} \) for long time. Our resulting diffusion model describes both the Batchelor and Richardson regimes and also predicts new phenomena not yet seen in experiment or simulations.

\(^1\)http://turbulence.pha.jhu.edu/

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