Particle Pair Dispersion in Free Surface Turbulence: On Intermittency and Divergence

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Turbulent pair dispersion is relevant to various phenomena including geophysics, meteorology, pollutant transport, and disease transmission, and represents one of the fundamental questions in turbulence research. Most of the previous work have focused on three-dimensional turbulence. The transport along the free surface of turbulent flows, however, is also omnipresent in nature and industrial settings, but our understanding in this area is still limited. Here we report an experimental study by 2D Lagrangian tracking of millions of tracer particles floating on the free surface of turbulent water. The experiments are carried out in a 2 cubic meter tank, with two arrays of submersed pumps firing jets at each other in randomized sequence[1], see Figure 1a. In the bulk, the Taylor-scale Reynolds number Re_λ ~600 warrants substantial scale separation, but the free surface is marginally deformed by the turbulence underneath. Applying Voronoi tessellation of the particle positions, the divergence of the surface velocity field is quantified by calculating the rate of change of the Voronoi cell areas[2], see Figure 1b. We find that the divergence is prevalently positive at small (near-dissipative) scales, which indicates that the compressible nature of the surface flow causes fast separation rates of nearby particles. Based on this observation, we present a generalization of pair dispersion by classifying particle pairs based on their initial separation rate. When this does not exceed the relative velocity prescribed by Kolmogorov theory, the expected scaling of the Eulerian velocity structure functions is retrieved. Moreover, the mean square separation of particles in the inertial sub-range is found to scale with time according to Richardson's theory[3]. These findings highlight the degree of applicability of classic results derived for incompressible turbulence to free-surface transport, while revealing specific features of this type of flows.

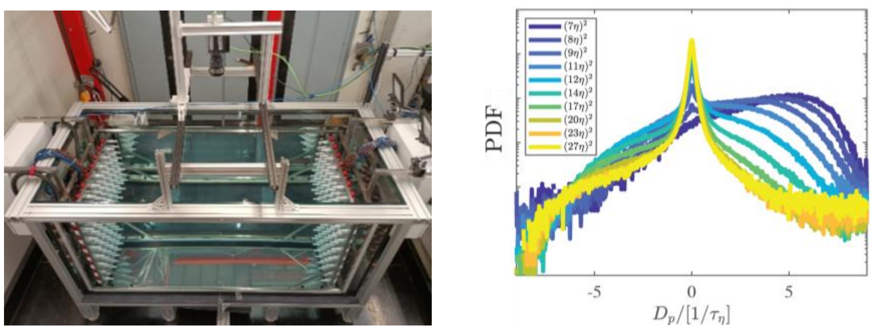

Figure 1: (a) the experimental facility and Water tank; (b) surface flow divergence

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[1] Variano and Cowen, *J. Fluid Mech.* **604**, 1-32 (2008).
[2] Oujia et al., *J. Fluid Mech.* **905**, A14 (2020).
[3] Richardson, *Proc. R. Soc. A* **110**, 709 (1926).