LAGRANGIAN MIXING IN WALL-BOUNDED TURBULENCE: A NETWORK PERSPECTIVE

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Turbulent mixing is undoubtedly a crucial mechanism in many natural phenomena and industrial applications involving turbulent flows. Due to its ability to enhance transport, turbulent mixing is a fundamental process to understand – among others – atmospheric dispersion, geophysical phenomena, as well as combustion mechanisms [1, 7]. In this work, to take advantage of the powerful capabilities of recent developments in network science, we propose a complex network-based approach to study turbulent mixing from a Lagrangian viewpoint [3]. In the last two decades, the application of complex networks has revealed several important insights in many research fields, including fluid flows [2, 4, 6, 8]. Here, we exploited a direct numerical simulation (DNS) of a fully-developed turbulent channel flow as a paradigm of possible applications. The DNS was run at $Re_\tau = Hu_\tau/\nu = 950$ for $T = 15200\nu/u_\tau^2$, where u_τ is the friction velocity, H is the half-channel height and ν is the kinematic viscosity [5]. A set of 100×100 fluid particles was initially released in the domain as a uniformly distributed grid in the plane (y^+, z^+) at $x^+ = 0$, where the streamwise, wall-normal and spanwise coordinates are (x^+, y^+, z^+), respectively. To build the network, particles were grouped into $N_y = 100$ wall-normal levels corresponding to the network nodes, each one comprising a subset of $N_z = 100$ particles. At any time, connections between particle pairs are active based on their spatial proximity: a particle i is connected to a particle j if i lies inside a reference ellipsoid centred in j, and *vice versa* (by symmetry). The ellipsoid was selected to consider the anisotropy of the flow: its semi-axes were set proportional to the average pairwise Euclidean distance between all particles, so that the effect of the streamwise dispersion on particle positions is captured. As a result, we obtained a time-varying network, in which nodes represent the y^+-levels, while link activation depends on the extent to which turbulent mixing affects particle dynamics. Since each node represents a set of N_z particles, each link is weighted, thus quantifying the interaction strength, E, as the total number of connections between particles in each node (see Fig.1a). The results show that the networks are fully able to capture the intensity of wall-normal mixing on particle dynamics, by highlighting characteristic mixing-advection regimes as well as the appearance of peculiar events (see Fig.1). Based on present findings, a promising tool is proposed, which can be exploited to extend the level of information of classical statistics for turbulence analysis.

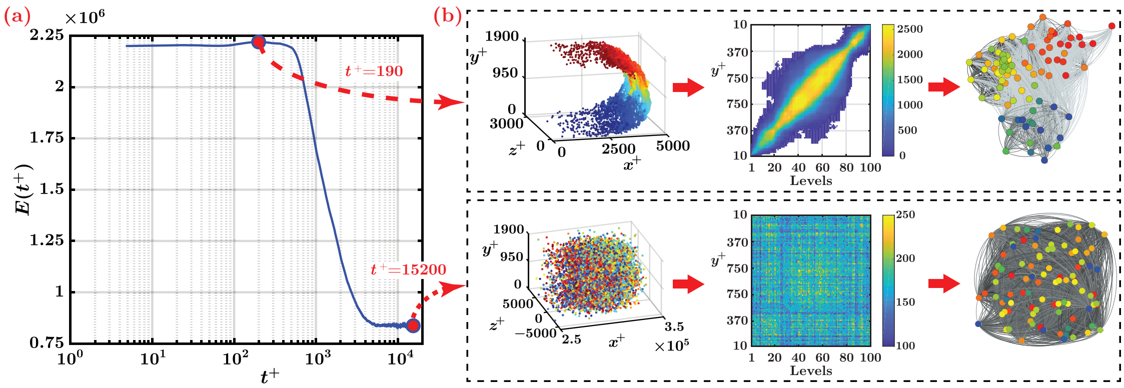

Figure 1. (a) Total number of particle connections, $E(t^+)$, as a function of time [3]. (b) From left to right: particle arrangment, link-weight matrix and corresponding network topology at $t^+ = 190$ (advection regime) and $t^+ = 15200$ (mixing regime). Node/particle colors indicate $y+$ values of levels, from blue ($y^+ = 0$) to red ($y^+ = 1900$).

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