SPECTRAL ANALYSIS OF THE EVOLUTION OF ENERGY-CONTAINING EDDIES

Ezhilsabareesh Kannadasan[1], Callum Atkinson[1] and Julio Soria[1]
Laboratory for Turbulence Research in Aerospace and Combustion (LTRAC),
Department of Mechanical and Aerospace Engineering,
Monash University,
Melbourne, Victoria 3800, Australia
E-mail: ezhilsabareesh.kannadasan@monash.edu.au

Energy-containing eddies are the elementary structures that carry most of the kinetic energy and momentum in wall-bounded turbulence. These eddies follow a self-sustaining cycle and can be structured in a hierarchical form attached to the wall. In this paper, the packets of energy-containing eddies are artificially quenched at the inlet of a turbulent channel flow direct numerical simulation (DNS), and the spatial evolution of the energy of the eddies is studied. The velocity fields from streamwise periodic channel flow (PCH-DNS) at Re_τ = *550* are filtered and used as the inlet velocity field for a channel flow DNS with inlet-outflow boundary conditions (IOCH-DNS). The turbulent transport spectra (Figure 1a) suggest that ridge λ_z = *3y* distinguishes the energy-containing eddies and the eddies involved in the energy cascade. The turbulent fluctuations and energy below the ridge λ_z = *3y* are removed, and only the eddies involved in the energy cascade are fed into IOCH-DNS at every time step. The mean velocity and fluctuating velocity profiles of IOCH-DNS are shown in Figure 1b, at x = *3h*, the mean velocity profile is distorted, and the streamwise fluctuation is evolved by extracting energy from the mean flow. The streamwise length of $24h$ is required to recover the turbulent fluctuations and energy when the energy-containing motions are removed at the inlet. At x = *24h*, the fluctuating velocity profiles are in good agreement with the PCH-DNS in the near-wall region, whereas, in the regions far from the wall ($y^+ > 150$) the fluctuations are damped. The pre-multiplied spanwise energy spectra of the streamwise velocity ($k_z\phi_{uu}$) of PCH-DNS are aligned along the ridge $\lambda_z = 10y$. In IOCH-DNS, as the flow evolves, energy starts to recover in the near-wall region ($y^+ \approx 10 \sim 15$) at a spanwise wavelength of $\lambda_z^+ \approx 100$, equal to the spanwise spacing of near-wall streaks, which indicates that the formation of near-wall streaks is the primary process in the recovery of energy-containing motions.

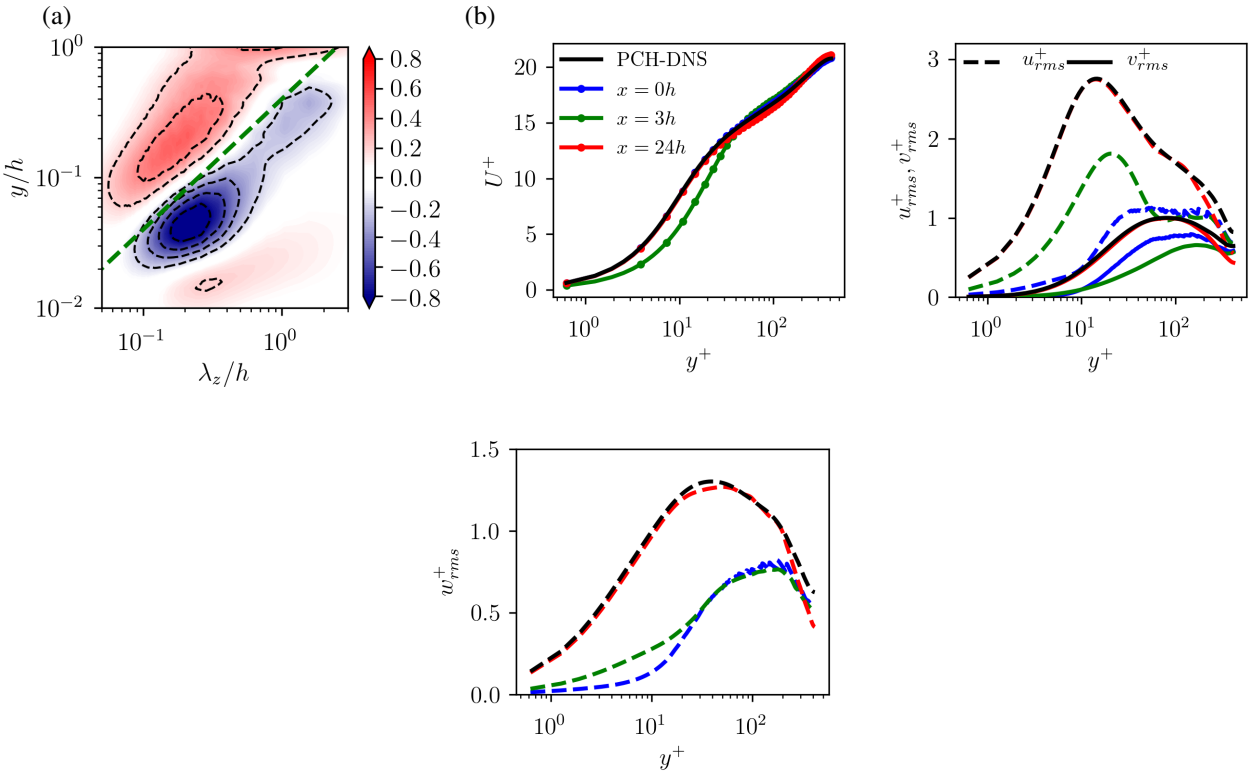

Figure 1. (a) The pre-multiplied spanwise spectra of turbulent transport ($k_z^+ y^+ \hat{T}^+_{\text{turb}}$) of PCH-DNS at $Re_\tau = 550$. Dashed green line is at $\lambda_z = 3y$, (b) Mean velocity profile and Root-mean-squared fluctuating velocity profiles at $Re_\tau = 550$. Here, black line, PCH-DNS; blue line, IOCH-DNS at x = *0h*; green line, IOCH-DNS at x = *3h*; red line, IOCH-DNS at x = *24h*.