Identification of dissipative flow structures using dissipation-optimised proper orthogonal decomposition

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We present a dissipation-optimised modal decomposition based on proper orthogonal decomposition (POD) of the strain rate tensor (SRT) in a turbulent channel flow[1]. The introduction of a spectral inverse SRT operator allows mapping of SRT modes to velocity modes, which let us expand any velocity-dependent quantity in terms of dissipation-optimised POD (d-POD) modes, and directly compare d-POD modes to turbulent kinetic energy (TKE)-optimised POD (e-POD) modes. The method is demonstrated using data extracted from direct numerical simulation of a turbulent channel flow with friction Reynolds number $\mathrm{Re}_\tau = 390$. Inspection of the lowest modes of either decomposition reveals both a richer small-scale structure in the d-POD mode compared to the e-POD mode, and the presence of large-scale structures in both modes.

Profiles of TKE, TKE production, and dissipation are reconstructed using either decomposition. While e-POD reconstructs structures in the channel bulk most efficiently, d-POD instead focuses on the near-wall region, achieving greater local efficiency than e-POD in reconstructing each quantity near the wall. Lower modes of either e-POD or d-POD contribute more to either reconstructed quantity. However, factorising modal contributions into eigenvalues and structural factors reveals that the structural contribution of e-POD terms to dissipation decreases with mode index, whereas the structural contribution of d-POD terms to TKE remains nearly constant. This suggests that modes throughout the d-POD spectrum describe structures spanning a range of scales, compared to the decreasing scale as a function of mode number which characterises e-POD modes.

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