Where do superstructures obtain their energy from?

Large-scale energy flux in turbulent pipe flow

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In Short

- Wall-bounded shear flows
- Coherent structures
- Inter-scale energy flux
- Direct numerical simulation

It is estimated, that half the energy being spent worldwide to move fluids through pipes and channels or to move vehicles through air and water is dissipated by fluid turbulence in the immediate vicinity of a wall [1]. Therefore, a detailed understanding of wall-bounded, turbulent shear flows is of utmost importance to all engineering applications where the Reynolds number is generally high.

Because of its unpredictable and highly chaotic behaviour, turbulence is typically studied as a stochastic process. In his ground breaking work, Kolmogorov [2] assumed that turbulent flows are isotropic and homogeneous at sufficiently small scales and showed precisely how energy is transferred from large to small eddies in a statistical sense. However, flows in nature and engineering usually feature anisotropic large-scale motions, which are often shaped by boundary conditions, geometry or source of driving. So in practice, turbulent flows are neither isotropic nor homogeneous. And the observed large-scale structures typically carry a substantial part of the kinetic energy of the flow and they can also determine its transport properties (mass, heat, momentum). Hence in order to go beyond state-of-the-art modelling and control strategies of turbulent flows, large-scale structures must be correctly accounted for.

This project aims at analysing the onset of large-scale structures in turbulent pipe flow and at clarifying whether these structures obtain their energy on the average form the mean shear or from smaller-scale structures. To this end, we perform highly resolved direct numerical simulations (DNS) in a large computational domain using our pseudo-spectral DNS code. To analyse the onset of superstructures, in a first step, we record and analyse the temporal development of the modal kinetic energy in selected small wave numbers while starting from fully-developed flow fields which do not contain energy in length scales larger than typical near-wall structures. Once, a statistically steady state with fully-developed large scale structures has been reached, we will – in a second step – compute one- and two-point statistics of the turbulent kinetic energy flux between different length scales based on spatial filtering and an adapted approach by Eyink [3].

WWW

www.zarm.uni-bremen.de

More Information

[1] J. Jimenez, *Ann. Rev. Fluid Mech.* **44 (1)**, p.27-45 (2012).

[2] A. N. Kolmogorov, *Dokl. Akad. Nauk SSSR* **30 (4)**, p.299-303 (1941).

[3] G. Eyink, *J. Stat. Phys.* **78 (1/2)**, p.335-351 (1995).

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