A look at the turbulent wake using scale-by-scale energy budgets

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It is now well established that coherent structures exist in the majority of turbulent flows and can affect various aspects of the dynamics of these flows, such as the way energy is transferred over a range of scales as well as the departure from isotropy at the small scales. Reynolds and Hussain (1972) were first to derive one-point energy budgets for the coherent and random motions respectively. However, at least two points must be considered to define a scale and allow a description of the mechanisms involved in the energy budget at that scale. A transport equation for the second-order velocity structure function, equivalent to the Karman-Howarth (1938) equation for the two-point velocity correlation function, was written by Danaila, Anselmet, Zhou & Antonia (1999) and tested in grid turbulence, which represents a reasonable approximation to (structureless) homogeneous isotropic turbulence. In the limits of large and small separations between the two points, the equation reduces to the one-point energy budget and transport equation for the enstrophy or energy dissipation rate respectively.

The equation has since been extended to more complicated flows, for example the centreline of a fully developed channel flow and the axis of a self-preserving circular jet. More recently, we have turned our attention to the intermediate wake of a circular cylinder in order to assess the effect of the coherent motion on the scale-by-scale energy distribution. In particular, energy budget equations , based on phase-conditioned structure functions, have revealed additional forcing terms, the most important of which highlights an additional cascade mechanism associated with the coherent motion. We have also examined in detail (Thiesset, Danaila & Antonia 2013) the dynamical effect of the total strain induced by the coherent motion on local isotropy both on and off the wake centreline, especially for the wake of a circular cylinder. Further insight into the effect of initial conditions has been gleaned by varying the geometry of the wake generator. In the intermediate wake, the magnitude of the maximum energy transfer clearly depends on the nature of the coherent motion. Finally, preliminary results for the scale-by-scale energy budget in the far wake will be discussed.