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Analysing and computing turbulent flows using wavelets

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Turbulent flows are characterized by their highly nonlinear dynamics and multiscale behaviour. We will show how the wavelet representation, which by construction is multiscale, efficiently analyze and compute turbulent flows. In the first part we will present the wavelet-based method we have proposed [Phys. Fluids, 11(8), 1999 - PRL 87(55), 2001 - Phys. Fluids, 15(10), 2003] to extract coherent vortices out of two and three dimensional turbulent flows. We will show that the coherent vortices are responsible for their nonlinear dynamics, as for their non-Gaussian statistics and long-range spatial correlation. In contrast, the remaining incoherent modes exhibit a diffusive behaviour, with quasi-Gaussian statistics and spatial decorrelation. In the second part, we will present the CVS (Coherent Vortex Simulation) method we are developing to compute turbulent flows [Flow, Turbulence and Combustion, 66, 2001 - J. Fluid Mech., 2005]. The main idea is to split each flow realization into two orthogonal parts, a coherent and an incoherent flow, using the previous wavelet-based method. We only compute the evolution of the coherent flow, while the incoherent modes are discarded at each time step to model turbulent dissipation. We have combined the CVS method with a volume penalization method to take into account solid walls. We illustrate this for homogeneous isotropic turbulent flows, flows in a rotating tank and flows past bluff bodies.

Papers can be downloaded from http://wavelets.ens.fr