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WAVELET-BASED COMPUTATIONAL MODELING OF WALL-BOUNDED TURBULENT FLOWS WITH LAGRANGIAN VARIABLE THRESHOLDING

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The ability to identify and efficiently represent coherent flow structures, along with self-adaptiveness and de-noising, have made wavelet-based methods very useful for developing multi-resolution variable fidelity approaches to the computational modeling of turbulent flows [1]. In the wavelet-based adaptive large eddy simulation (LES) approach, the separation between resolved energetic structures and unresolved residual flow is obtained through nonlinear wavelet threshold filtering (WTF). The filtering procedure is accomplished by applying the wavelet-transform to the unfiltered velocity field, discarding the wavelet coefficients below a given threshold ϵ and transforming back to the physical space. This way, the turbulent velocity field is decomposed into two different parts: a coherent more energetic velocity field, which is computed, and a residual less energetic coherent/incoherent one, whose effect is approximated through subgrid-scale (SGS) modeling [2].

The key role in the method is played by the thresholding level ϵ, which explicitly defines the relative energy level of the resolved turbulent eddies and, consequently, controls the importance of the residual field influence to be modeled. Since its inception, the adaptive LES approach has been adopted with *a priori* prescribed thresholding parameter. However, when dealing with complex turbulent flows, the energy content of the dominant coherent structures to be resolved can significantly vary, so that the desired level of turbulence resolution can not be maintained without modifying the thresholding level. A time-dependent wavelet thresholding method has been recently introduced and successfully tested for the computational modeling of homogeneous turbulent flows, where the uniform WTF level is evolved in time according to a simple feedback control equation [3].

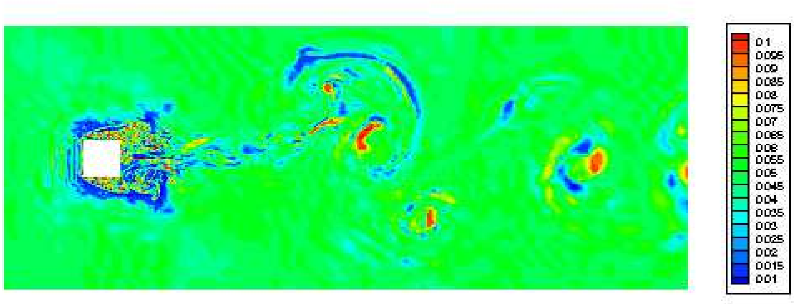

Figure 1: Contours map of the WTF level at a given time instant.

In this work, a new spatially and temporary varying thresholding procedure that consists in tracking the WTF threshold within a Lagrangian frame, by directly solving the corresponding evolution equation and exploiting a path-line diffusive averaging approach, is used. The method, which has been proposed in [4] and therein tested for forced isotropic turbulence, is here applied to the computational modeling of wall-bounded flows, where the flow geometry is enforced through Brinkman volume-penalization. The wavelet-collocation/volume-penalization combined method is applied to the simulation of vortex shedding flow behind an isolated stationary prism with square cross-section. Wavelet-based adaptive LES supplied with the one-equation localized dynamic kinetic-energy-based model [2] is performed at moderately high Reynolds number.

The present method of physics-based Lagrangian varying thresholding fully exploits the spatial/temporal intermittency of turbulence, thus, overcoming the major limitation for wavelet-based multi-resolution techniques that make use of a constant and uniform thresholding criterion.

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