A vorticity-based closure for LES

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We present the properties and the performances of a new implicit large eddy simulations (ILES) code based on the covariant form of the momentum equations, a.k.a the vector-invariant form. The sub grid-scale closure is implicit because it is achieved by the numerics solely, and specifically by upwind discretizations of the terms responsible for mixing and dissipation at the grid-scale. For the density, it is a classic flux upwinding. For the momentum, the upwinding[1] is done on the vortex-force term $\boldsymbol{\omega} \times \mathbf{u}$, where $\boldsymbol{\omega} = \boldsymbol{\nabla} \times \mathbf{u}$ is vorticity. The resulting parameterization, although purely numerical, satisfies several important invariances: scaling, translation, rotation, and in general, coordinates change invariance, thanks to the covariant form. By construction, the closure control parameters are numerical: the order of interpolation (3rd or 5th) and its nature (linear or nonlinear). The parameterization, tested on classical and well referenced turbulent flows, turns out to be very accurate with WENO reconstructions. Figure 1 illustrates the breaking of an interfacial wave, once the three dimensional turbulence has kicked in, triggering the mixing. The mixing and the energy dissipation is provided by the implicit closure exclusively. We show how this approach compares to other LES. This parameterization opens up interesting perspectives on the broader issue of turbulent closure because by dropping out the Reynolds stress, it makes the vorticity the central player of the closure.

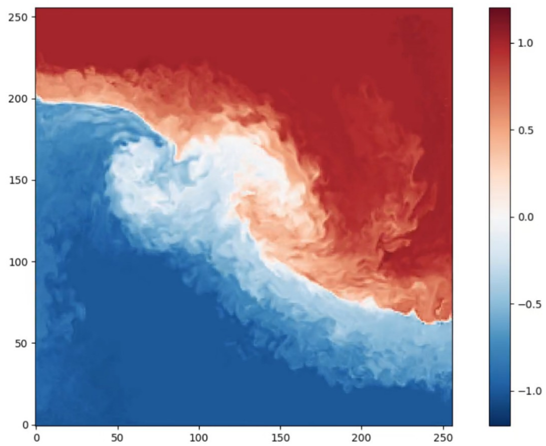

Figure 1: Vertical section of buoyancy in an initially two layers system with a slanted interface, in a 256^3 cubic domain.

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