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A sub-grid scale model with natural near-wall damping

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Abstract

A zero-equation sub-grid scale (SGS) model with a variable eddy-viscosity coefficient C_μ is developed for large-eddy simulation. Since C_μ is evaluated based on the resolved shear and vorticity parameters accompanied by the hybrid time scale T_t (combination of dynamic and Kolmogorov time scales), it is sensitized to non-equilibrium flows, preserving the anisotropic characteristics of turbulence. The current model accounts for the SGS kinetic energy with $k_{sgs} = C_\mu^{\frac{2}{3}} (\bar{\Delta S})^2$ and guarantees the positivity in the energy components. Unlike the original Smagorinsky model, the present SGS model does not need any *ad-hoc* damping function (C_μ acts as a natural damping function as the wall is approached) or averaging/clipping of the model coefficient for numerical stabilization as required by the dynamic Smagorinsky model (DSM). The model is validated against well-documented flow cases, yielding predictions in good agreement with the direct numerical simulation (DNS) and experimental data. Comparisons indicate some advantages of the new model over the DSM; the current model needs only a single-filtering operation that recovers the numerical stability and computational effort to a greater extent.

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