# NEW SUBGRID-SCALE MODELS AND CHARACTERISTIC LENGTH SCALES FOR LARGE-EDDY SIMULATION OF ROTATING TURBULENT FLOWS

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Rotating turbulent flows form a challenging test case for large-eddy simulations with commonly used eddy viscosity models. We therefore consider subgrid-scale models with an additional term, which is nonlinear in the local velocity gradient,

$$\tau^{\text{mod}} - \frac{1}{3}\operatorname{tr}(\tau^{\text{mod}})I = -2\nu_e S + \mu_e(S\Omega - \Omega S). \tag{1}$$

Here, $S$ and $\Omega$ represent the rate-of-strain and rate-of-rotation tensors, respectively. The usual eddy viscosity term parametrizes dissipative processes in turbulent flows. The nonlinear term is perpendicular to the rate-of-strain tensor. Therefore, it does not directly contribute to the subgrid dissipation and it represents energy transport.

The eddy viscosity, $\nu_e$, and the transport coefficient, $\mu_e$, are defined in terms of a model constant, a (squared) length scale and a velocity-gradient-dependent factor. We base this latter factor on the vortex stretching magnitude, which corrects for the near-wall scaling and dissipation behavior of the Smagorinksy model [2].

As the nonlinear term contains the rate-of-rotation tensor, the subgrid-scale model of Eq. (1) has “a particular potential for [the simulation of] rotating flows” [1]. Figure 1 shows results of large-eddy simulations of rotating decaying homogeneous isotropic turbulence, indicating that the nonlinear model term leads to an improved prediction of energy transfer [3].

Large-eddy simulations of spanwise-rotating plane-channel flow, performed on stretched anisotropic grids, further indicate that numerical results are sensitive to, and sometimes adversely affected by, the choice of the subgrid characteristic length scale [3]. We therefore propose to replace the purely grid-based characteristic length scale employed in these simulations by the flow-dependent length scale given by [3]

$$\delta_{\text{lsq}} = \sqrt{\frac{G_\Delta G_\Delta^T : GG^T}{GG^T : GG^T}}. \tag{2}$$

Here, $G$ and $G_\Delta$ represent the velocity gradient in the physical and computational space, respectively. The length scale of Eq. (2) was shown to reduce the dependence of numerical results on mesh anisotropy [3].

We will assess the nonlinear subgrid-scale model of Eq. (1), in conjunction with the characteristic length scale of Eq. (2), using simulations of rotating channel flows.

## References

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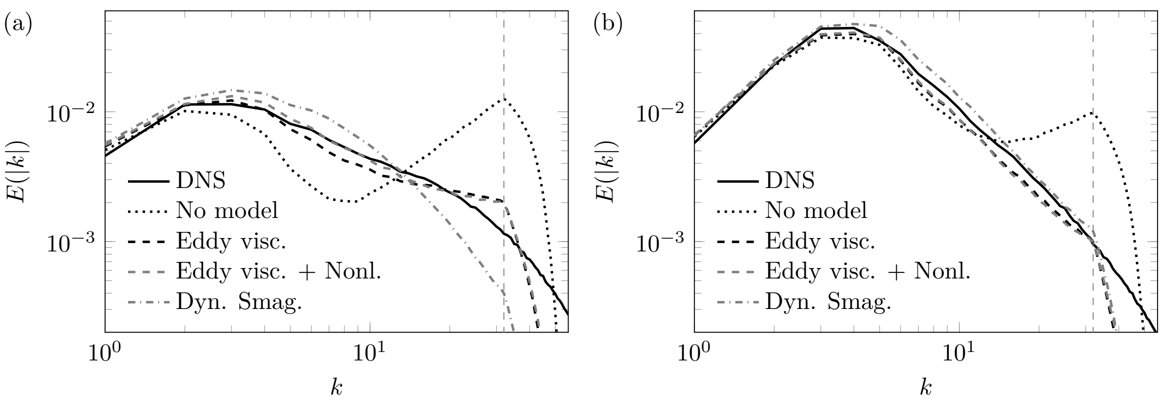


**Figure 1.** Three-dimensional kinetic energy spectra as a function of computational wavenumber for homogeneous isotropic turbulence at rotation number (a) $Ro = 0$ (no rotation) and (b) $Ro = 100$ (significant rotation).