Vortex tubes, spirals, and large-eddy simulation

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Quasi two-dimensional vorticity distributions such as vortex tubes, sheets, and spiral structures have achieved some success in the quantitative modeling of the small scales of turbulence. This research started in the 1950s with the use of axisymmetric Burgers vortices by Townsend to model the dissipation range of the turbulence velocity spectrum. A major advance was made by Lundgren [1] who replaced the Burgers vortex by a generalized non-axisymmetric stretched spiral structure.

This talk will survey some recent applications of stretched vortex tube/spiral models to the estimation of turbulence statistics for both isotropic and non-isotropic flows. An approach to the large-eddy simulation of turbulent flows based on the stretched-vortex subgrid stress model [2] will be described. In this approach the unresolved (subgrid) velocity field is modeled by nearly axisymmetric subgrid vortices - one or more per grid point - whose axis alignments are related to the local resolved-flow velocity gradients. The subgrid stresses produced by the vortices are proportional to the product of the vortex energy and a second-order tensor determined by the vortex axis directions. Closure is obtained when Kolmogorov-like forms of the subgrid energy spectrum are assumed, or alternatively, when the vortices are assumed to be of the Lundgren stretched-spiral form. Methods of determining model parameters based of the second-order velocity structure functions of the resolved flow will be discussed. Applications of the model to decaying turbulence, incompressible channel flow and to the statistics of a passive scalar in forced isotropic turbulence will be described. Finally, recent work on the application of vortex tube and vortex spiral models to the scalar spectrum produced by small scale mixing of a passive scalar will be discussed.

References

[1] T.S. Lundgren. Strained spiral vortex model for turbulent fine structure. *Phys. Fluids*, 25:2193-2203, 1982.

[2] T. Voelkl, D. I. Pullin, and D. C. Chan. A physical-space version of the the stretched-vortex subgrid-stress model for large-eddy simulation. *Phys. Fluids*, 12:1810-1825, 2000.